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PB 256 845

HEALTH, ENVIRONMENTAL EFFECTS, AND CONTROL TECHNOLOGY OF ENERGY USE

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SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO.
EPA-600/7-76-002

2.

3. RECIPIENT'S ACCESSION NO.

4. TITLE AND SUBTITLE
Proceedings, U.S. EPA, OEMI National Conference on Health, Environmental Effects, and Control Technology of Energy Use.

5. REPORT DATE
February 1976

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)
Over sixty papers and 100 authors are represented in the proceedings.

8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Symposium Proceedings prepared by:
The MITRE Corporation
1820 Dolley Madison Blvd.
McLean, Va. 22101

10. PROGRAM ELEMENT NO.
EHE623

11. CONTRACT/GRANT NO.
68-01-3188

12. SPONSORING AGENCY NAME AND ADDRESS
U.S. Environmental Protection Agency
Office of Energy, Minerals, and Industry
Washington, D. C. 20460

13. TYPE OF REPORT AND PERIOD COVERED
Final

14. SPONSORING AGENCY CODE
EPA-ORD

15. SUPPLEMENTARY NOTES

16. ABSTRACT

These proceedings include the addresses and papers reported at the National Conference on Health, Environmental Effects, and Control Technology of Energy Use held in Washington, D. C., February 9-11, 1976. The symposium was sponsored by the U.S. Environmental Protection Agency Office of Energy, Minerals, and Industry. Sixty papers are presented representing the work of 17 Federal Agencies active in the research and development directed at protection of the nation's environment.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Environmental engineering	National Conference	02 18
Energy	Energy Use	04
Pollution	Environmental Effects	06
Research projects	Control Technologies	07
National		08
Meetings		10
		13

18. DISTRIBUTION STATEMENT Release Unlimited	19. SECURITY CLASS *(This Report)* U.C.	21. NO. OF PAGES 347
	20. SECURITY CLASS *(This page)* U.C.	22. PRICE 10.00

EPA Form 2220-1 (9-73)

PRICES SUBJECT TO CHANGE

Proceedings of:

National Conference on

HEALTH, ENVIRONMENTAL EFFECTS, AND CONTROL TECHNOLOGY OF ENERGY USE

February 9-11, 1976
Sheraton Park Hotel
Washington, D.C.

Sponsored by:
The Office of Energy, Minerals and Industry, within the
Office of Research and Development of the U.S. Environmental Protection Agency

FOREWORD

Since fiscal year 1975, approximately $230-million has been allocated to the coordinated Federal Energy/Environment Research and Development Program. The success of the seventeen government agencies participating in this program requires close cooperation and timely exchange and dissemination of the results of the ongoing research. To assist in this communications effort, the National Conference on Health, Environmental Effects, and Control Technology of Energy Use was held in Washington, D. C., February 9-11, 1976.

These proceedings include the addresses and papers reported at the conference. We have also transcribed and edited the questions and discussions stimulated by each of the conference sessions.

The Office of Energy, Minerals, and Industry within EPA's Office of Research and Development is pleased to have been able to sponsor this symposium. We consider it to be an important part of carrying out our responsibility to plan and coordinate the entire Interagency Program. It is our hope that the dialogue presented in this and other program documents will contribute to the necessary task of information exchange within the organizations involved in energy-related environmental research and development. We are indebted to the participating individuals and to their agencies.

These proceedings represent a compendium of current and planned work. I hope that you will find the publication of interest and of use, especially in pursuit of our common national goal of increased energy development in an environmentally compatible manner.

Stephen J Gage

Stephen J. Gage
Deputy Assistant Administrator
Office of Energy, Minerals and Industry
U. S. Environmental Protection Agency

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ACKNOWLEDGMENT

More than one hundred authors contributed to the more than sixty papers reported at the symposium. Comprehensive description of the environmental program would not be possible without the invaluable assistance of these individuals and their agencies.

Special acknowledgment should also be given to Mr. David J. Graham of the Office of Energy, Minerals, and Industry who acted as the symposium coordinator; Mr. Richard A. Kennedy, of The MITRE Corporation's Energy, Resources and The Environment Division who provided technical, planning and organizational support to the symposium coordinator; and Mr. Harold Bernard, Information Transfer, Inc., who arranged the symposium and provided for publication of these proceedings.

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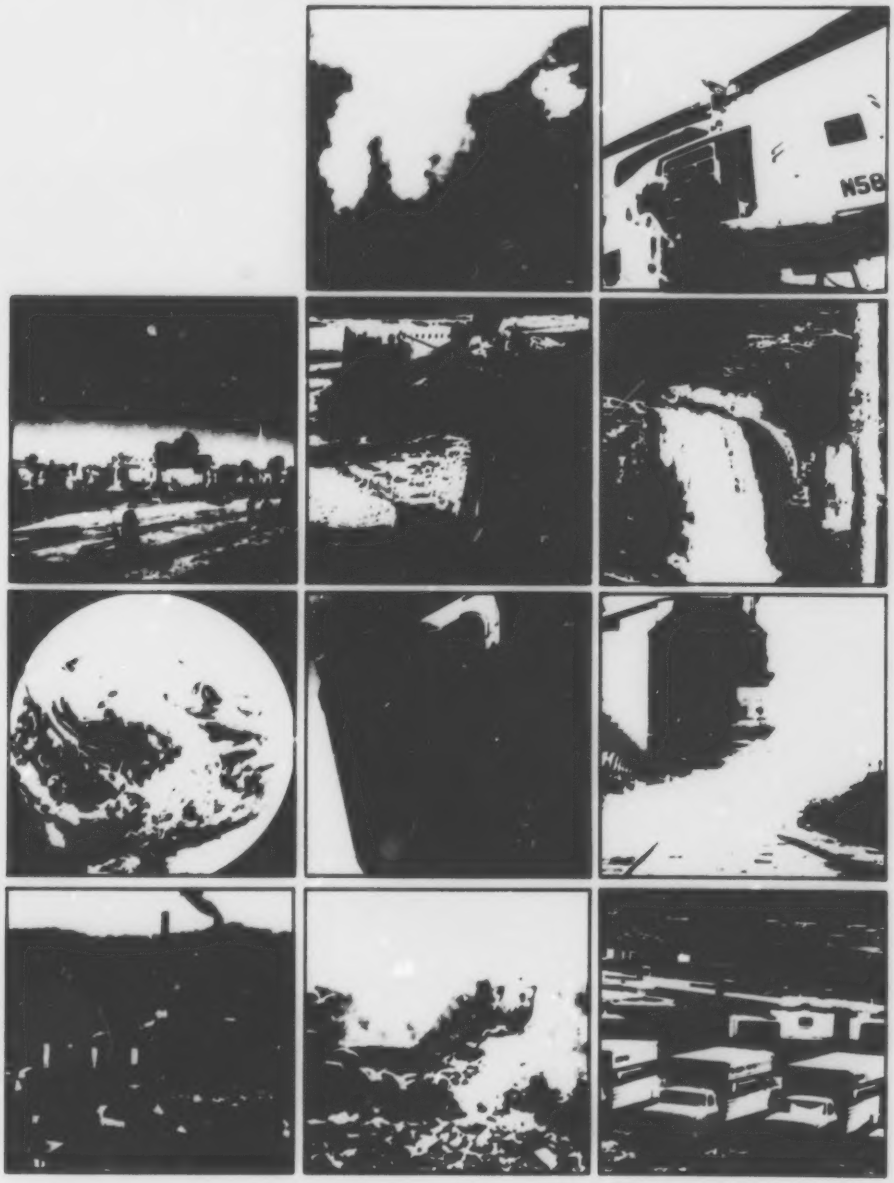
CHAPTER 1

WELCOME AND OVERVIEW



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Welcome Address

by
Dr. Wilson K. Talley

I am pleased to welcome you to the National Conference dealing with research and development programs on Health, Environmental Effects, and Control Technology of Energy Use. This large audience indicates, I believe, the broad base of interest in two of the Nation's principal concerns: energy and the environment. The participation of many representatives today from the private and public sectors is indeed gratifying.

Before I introduce our speakers this morning, I would like to describe briefly the role of research and development in a regulatory agency. For the most part, I will constrain my remarks to our energy-related activities.

The Environmental Protection Agency is required to administer environmental legislation to control and abate adverse impacts on the human environment--in a comprehensive and balanced manner--consistent with the attainment of other national goals. As a consequence, EPA and its predecessor components have been concerned with pollution control for the energy-related industries for several years. The legislation which EPA must administer, bearing on energy development and use, includes the Clean Air Act, the Federal Water Pollution Control Act, the Resource Recovery Act and the Marine Sanctuaries (Ocean Dumping) Act.

Some of this legislation specifies the constraints to be imposed, such as, best practical control technology or best available control technology, to be required within given time periods. The many activities that the agency is required to engage in include:

(1) development of standards, regulations and/or guidance

(2) performance of environmental monitoring (surveillance and compliance assessment)

(3) performance of environmental impact assessments

(4) providing training and technology assistance.

In addition, we engage in research, development and demonstration in areas such as health effects, ecological effects, environmental processes and quality, environmental management, pollution control systems, and instrumentation.

While it is true that the National Environmental Policy Act requires federal agencies to assess the environmental impact of their respective activities, EPA has the further responsibility to evaluate the environmental impact of all federal programs in all areas of its expertise.

NEED FOR RESEARCH IN A REGULATORY AGENCY

Fundamental to any regulatory agency is the need to have accurate and reliable information on which to base decisions. Since the regulatory process is dynamic, iterative and continuing, the need for information is also dynamic, time-sensitive and often very specific. The function of research in a regulatory agency is to provide the necessary data base and tools required by the agency to fulfill its obligations on a timely basis. The research, therefore, should be mission-oriented, the research mission being dictated (either explicitly or implicitly) by the creating executive order and/or the legislation to be administered.

Now, how should the research information required by a regulatory agency be obtained? At one extreme, specific regulatory agency offices can carry out all of the needed research; at the other extreme, the regulatory agency can rely solely on whatever information is being generated outside its own control.

While examples of each of these extremes exist, most regulatory organizations operate somewhere in the middle with the research information needed coming from a combination of in-house and extramural research programs, only a portion of which is under the direct control of the entity having the need.

ORGANIZATION OF ORD

Within EPA, a decision was made that the Agency's research effort would be managed by a separate research arm - the Office of Research and Development. As an equal to the regulatory and enforcement arms of the Agency, the research group could assure that the best technical input could be made on a timely basis and still maintain the capability to look ahead and across the different regulatory programs of air, water, noise, pesticides, solid waste, radiation and toxic substances. However, EPA's research arm need not do everything itself, rather it is obliged to be aware of what is going on outside the agency, to coordinate efforts where possible and to perform research in those areas specified by the legislation or interagency agreement and, on those subjects not receiving sufficient emphasis, to provide the information required for agency decisions on a timely basis. The Office of Research and Development is EPA's focal point for specialized research, relying on processes of information and funding transfer to make sure that the total research effort is adequate and well articulated. As a consequence, EPA's research is supplemented by general scientific and technical research in other governmental agencies, colleges and universities, the industrial sector, and elsewhere.

The research program in EPA is carried out through four major program offices and their respective laboratories. These are the Office of Energy, Minerals, and Industry, the Office of Air, Land and Water, the Office of Health and Ecological Effects, and the Office of Monitoring and Technical Support. Because of the complexity of environmental research and development, the need to relate our output to a variety of different users and the need to avoid duplication of talent and other resources, it has been necessary to differentiate between planning and implementation of many of the programs. Thus, for example, the entire program on environmental impact of energy use is planned in our Office of Energy, Minerals, and Industry but is implemented by all four offices. To accomplish this objective, OEMI allocates the energy related budget amongst all offices during the planning process and transfers to the other three offices the funds necessary to cover the planned energy-related work being implemented by those offices. The implementing office has the responsibility for accomplishing the energy-related program for which it has accepted funds. The managers of the implementing laboratories are at liberty to determine whether an intramural or extramural approach will be used subject to their respective constraints on manpower, facilities and funds. The extramural programs include interagency, university, and industrial cooperation.

During the next three days, detailed descriptions of this coordinated effort will be provided by technical experts from many federal agencies. I trust you will find the proceedings to be interesting and rewarding. I hope that a lively dialogue will develop in the discussion periods which begin in Session II this afternoon.

Keynote Address
by
Russell W. Peterson, Chairman
Council on Environmental Quality

TWO-HANDED SCIENTISTS:

According to revered tradition, the keynote speaker in American life has a clearly defined role: he is supposed to tell a few warm-up jokes and then end on a solemn, inspirational note -- a blend of Johnny Carson and Sermonette. Traditionalist that I am, I have always tried to honor these conventions. In my previous incarnations, this was reasonably easy to do: there are a few chemistry jokes, lots of businessman jokes, and even a few governor jokes. And as for solemnity, that's the easiest part of the job: all one need do is bang on the podium and summon the audience to meet, quote, the challenge that lies before us, unquote.

Some day, just for fun, I would like to summon an audience to meet the challenge that lies behind us. I shall not do that today. Nor shall I open with a joke, because the environmental movement seems to have produced only one -- and we've all heard it. Hence, I shall spare you Moses and his environmental impact statement.

By way of recompense, let me recount a parable instead. It was, as far as I can determine, either invented or translated by the English writer Somerset Maugham, and later borrowed by John O'Hara for the title of his first novel. It goes like this:

> The chief steward of a wealthy merchant in ancient Basra went into the marketplace one day, and there he encountered Death, dressed as an old woman. On seeing the steward, Death suddenly drew back. In great terror, the steward returned immediately to the merchant's house and said, "Master, today I saw Death in the marketplace, and she made a menacing gesture at me. Please let me ride away to Samarra, so that I can escape."
>
> The merchant replied, "By all means, take my fastest horse and ride." Later that same day, the merchant himself went into the marketplace and he, too, saw the old woman. He stopped her and said, "My servant told me that he met you here this morning, and that you threatened him."
>
> And Death replied, "Oh, no -- I did not threaten him. I was just surprised to see him here in Basra, because tonight I have an appointment with him in Samarra."

As its most obvious level, this parable is about fate: it suggests that man cannot avoid what is in store for him no matter how hard he tries. While such a fatalistic attitude may hold true in other cultures, it would be rejected by most of us as ridicuously exaggerated. Yet the additional twist of the steward riding as rapidly as he can to meet the very fate he fears contributes a thought-provoking subtlety: it implies that man's dash for apparent salvation, if undertaken impulsively and with inadequate knowledge, can hasten rather than circumvent his destruction.

The Arab oil embargo gave us a severe scare in the marketplace in 1973, and has motivated us to race into the development of advanced energy technologies which, in normal circumstances, would have been developed at a more leisurely pace. As matters stand now, most air pollution is a result of the production or use of energy. As we get into new technologies, or expand those which are presently small in scope -- from coal gasification to breeder-reactors -- we shall have to anticipate not only an increase in the number of environmental hazards, but also an increase in their complexity.

The Federal Interagency Energy/Environment R&D program is an attempt to insure that our understanding of the health effects of energy development and use keeps pace with technological development -- to make sure that we do not begin using a new technology on a widespread scale before we know what it will do to our air, water, and soil -- and, ultimately, to human health.

As you undoubtedly appreciate, this could prove a tricky juggling act. We are involved in two kinds of research: into energy development, and into the environmental effects of that development. Though the two are clearly related, however, they will not necessarily proceed at the same pace. We may, for example, be able to establish the environmental effects of a new technology before we can demonstrate its economic feasibility. In such cases, we will probably be able to avoid harmful side-effects entirely or, at a minimum, mitigate those side effects through control technology.

But on the other hand, some energy research and development may proceed more quickly than the related environmental research. And in that case, we may be in trouble. Already, for national security as well as economic reasons, there is strong pressure to tap new domestic energy sources as rapidly as possible. Should a new source be ready for commercial utilization before its environmental implications are well understood, it's questionable whether the necessary cautions from scientists will be able to withstand popular demands for more energy.

As the Manhattan Project demonstrated, the pressure of external events may successfully accelerate a certain line of scientific research. In that case, a war speeded up R&D that had begun years earlier, but was proceeding at a slow pace; then the demands of national defense, which characteristically throw all considerations of fiscal constraint out the window, led us to devote an abnormal amount of money and highly trained manpower to atomic fission. Thus a project which, under normal circumstances, might have required 20 years to accomplish was rushed -- under the stress of war -- to completion in four years.

Yet money and expertise are not the only constraints on research, and science can be hurried only up to a point. There is, in scientific investigation, an inherent process of sequential analysis -- of taking one step after another -- that cannot be rushed, no matter how much urgency, money, and manpower you are willing to devote to the job. Luck may sometimes produce a short-cut, but more resources do not necessarily speed the process.

Cancer research is an example. A few years ago, President Nixon declared a "War on Cancer," and substantially increased the amount of resources that had been devoted to such research. Since then, a considerable amount of worthwhile scientific work has been undertaken, and perhaps some has been completed sooner than it normally would have. Yet the ultimate goal -- a cure for cancer -- still eludes our grasp. We know that the fundamental nature of cancer is unrestrained growth of cells. We know that this growth is associated with a number of environmental causes: cigarette smoking, the presence of certain chemicals in the living or working environment, radiation from certain minerals and from the sun itself. Yet we have not been able to define the cancer-causing mechanism well enough to cure most cancers, despite the stepped-up investment of funds.

An analogous case in a broader sphere was President Johnson's "War on Poverty." Just as in the case of the "War on Cancer," there seemed to be an underlying assumption that if x dollars can produce some good, 10x dollars can produce 10 times as much good in the same period of time. But here again, even though we can associate poor scholastic achievement, cultural deprivation, and other symptoms of poverty with the basic fact of poverty, we still do not understand the poverty-causing mechanisms well enough to change their operation. Lacking that fundamental understanding, we tried to substitute dollars for science -- and we reaped little more than disappointment from our well-meant, but immature and expensive experiment. The real pity is not that we may have wasted considerable sums of money, but that the long, slow process of social improvement may have lost popular support for years to come.

Despite such failures, the fundamental misconception that science can be hurried with money probably remains in the popular and political mind. Another misconception is an exaggerated belief in the ability of scientists to produce certitude on schedule. Years ago, President Truman was briefed by the first chairman of the Council on Economic Advisers. Exercising the caution proper to his discipline, this gentleman reputedly framed all his remarks in the context of such statements as, "On the one hand, this might happen ... But on the other hand, that might happen." After an hour or so of this, following the economist's departure from the Oval Office, President Truman is said to have complained to an aide, "What we need around here is a one-handed economist."

This understandable impatience with ambiguity, and a craving for certainty even though all the facts are not in, characterizes most of us to some degree. It is particularly to be found in decision makers, and it persists today. Last year, for example, Senator Muskie called for "one-armed scientists" after testimony from a number of them, concerning the health effects of pollutants, proved to be inconclusive. The decision-maker must act -- and more and more, in our age, the decision-maker turns for "facts" that will simplify difficult choices.

In a better world, perhaps the critical choices that we will have to make about energy in the next years and decades would await the findings of environmental scientists. No project would go on line before we knew precisely what it would do to our ecosystem, and had fashioned the proper safeguards.

But for lack of a better world, we are forced to make do with the one we have -- and it is a world in which energy production appears to be the great global imperative. Policy makers will be pressing scientists for hard conclusions before any conclusions are justified by hard evidence. It would be simple to urge that we reject any such pressures in the interest of scientific purity -- but in point of fact, we will probably have to accommodate those pressures. Except in the face of the clearest, most definitely established environmental hazards, energy development won't wait. The problem, then, is not one of adopting high principle, but of charting prudent strategy.

That means, first, establishing research priorities. Prior to 1974, when this Federal interagency research program was created, top priority was assigned to investigating and preventing the harmful health effects of coal-burning. The rationale for this choice was logical and sound: our immense coal resources promised to make the most immediate contribution to our energy requirements, whereas other sources tended to be further off on the horizon. Hence the questions we would have to answer soonest were those related to coal-consumption.

Now, however, the choice of priorities is becoming more difficult. Every technology has a probable time-line -- a rough schedule, usually expressed in years, when one stage of development will have to be made. Such decisions, for example, might involve a shift from laboratory-scale tests of a new technology to the construction of a pilot facility; later on, from the pilot to a demonstration facility; and finally, from the construction on a demonstration facility to full-scale, commercial development.

Thus some decisions will have to be made in the next couple of years, while others may not confront us for four, six, or more years. Research priorities must be assigned in accordance with the probable development schedule for each technology; only such phasing-in will ensure that, at every decision-point, the appropriate environmental research will be available. If it's not, non-scientific pressures -- including public demand for more energy, and political demand for action to satisfy the constituency -- are likely to force a decision, even on the basis of inadequate data. Judging by past experience, my hunch will be that energy development, not environmental protection, will get the benefit of the doubt.

It is partly CEQ's responsibility to oversee your choice of priorities -- to make sure the answers that will be needed two years from now are being sought now. We simply do not have the luxury of time. Every technology that we are considering presents certain unknowns and -- if we had the leisure that science requires -- we would insist that energy development wait until each of those unknowns was fully investigated. But our limited resources -- above all, time -- make it impossible for us to examine these unknowns with all the thoroughness that each deserves. Relatively quick and inexpensive analysis may suggest that some negative environmental consequences are either so likely or so unlikely that additional R&D would not change the decision. Therefore, our environmental R&D should be directed toward those unknowns where the outcome is less clear but potentially significant.

Second, we must make maximum use of Federal leverage in energy development. Under normal circumstances, private enterprise would pay the bill for developing new energy technologies. Owing to the sensitivity of some of these technologies, however, the massive amounts of capital their development requires, and the national urgency of tapping new energy resources, the Federal government has agreed to underwrite some of the risk involved, through such devices as direct support for demonstration.

This offers the opportunity to make close monitoring of environmental consequences an integral part of Federally supported energy development projects. At present, much of the data we have on emissions from new and emerging technologies is based on information from pilot plants and small-scale operations. The move from these small operations to commercial sized demonstration plants gives us a unique opportunity to use these plants as environmental laboratories. We should use this opportunity, from the beginning of the R&D process, to prevent the creation of environmental "white elephants" -- projects that later require huge investments in add-on control technology.

A third priority must be to correlate emissions and health effects. Over the last three years, CEQ has encouraged the development of quantitative methods for estimating the environmental impacts of energy facilities. Examples of such work are the MERES Study and the Energy Alternative reports, with which most of you are probably familiar. Valuable as these efforts are, they do not yet allow us to translate a given quantity of pollutants into the number of cases of various human ailments that will result.

But finally, we must bear in mind -- through all this research -- the fundamental interrelatedness of environmental impacts. Man breaks scientific endeavor down into specific disciplines for his own convenience, and hence perceives reality from different perspectives. Such specialization has been necessary for scientific and technological advance; we have learned much more, and much more quickly, by breaking phenomena down into various compartments and studying them from the standpoints of biology, physics, chemistry, and so forth.

But we must remember that our ecosystem does not exist in compartments; it comes in single, interrelated communities, each part of which affects other parts. It does no good, for example, to consider only the effects of oil-shale development in one part of the country, when at the same time, strip or deep mining is to be conducted in the same region. Both will demand extensive water supplies, and the drawing-down of the water table, plus the disruption of coal veins that often serve as aquifers under the ground, can affect agriculture, grazing, and even human drinking supplies. Not by energy alone does man live. While pursuing our separate disciplines, each of us must strive to relate our work to that of other specialists, so that we can regain -- by adding our individual pieces to the total puzzle -- a view of the unity exemplified in nature.

This is, I realize, a tall order. It will not be filled by one-handed scientists -- by suppressing ambiguity in order to simplify decisions or to avoid the wrath of impatient decision-makers. Nor, on the other hand, will it be filled by the leisurely pursuit of pure science. We are in a tough, nuts-and-bolts situation, and we must do the best we can to blend painstaking science with the sense of urgency that the national energy situation requires. Only by achieving this blend -- by making haste slowly -- can we hope to obtain the information we need when we need it.

We are not entirely at the mercy of a blind fate. The entire history of science is the history of man's attempt to understand natural forces and shape them to his own benefit. The advent of an environmental consciousness is not a repudiation of our science, but a challenge to us to extend it. It has taught us that man is not entirely master of his environment, but a member of it, who must learn to live in harmony with the natural world.

New energy technologies beckon us down many different roads, with their promise of abundant supplies of the fuels on which we have built our civilization. Yet their promise must not be permitted to blind us to the threat such development poses to our ecosystem, on which man's very existence is built. It is up to you to ride ahead on these many roads, and to discover as quickly as possible where they lead. Only your scientific scouting can guide us to the sufficiency we seek -- and prevent us from dashing, as quickly as we can, to keep an appointment in Samarra.

REMARKS OF THE HONORABLE GEORGE E. BROWN, JR.

Chairman, Subcommittee on Environment
and the Atmosphere of the Committee
on Science and Technology

A CONGRESSIONAL VIEW

I am delighted to be here today to address this large group of people involved in making energy use compatible with a clean and healthy environment. I believe this conference is an excellent initiative by the Office of Research and Development of the Environmental Protection Agency, and I hope this type of activity continues in the future. We, in Congress, are always pleased when we see examples of interagency communication and cooperation.

As you probably know, the Subcommittee on Environment and the Atmosphere, which I chair, is part of the Committee on Science and Technology, which until a little over a year ago was the Committee on Science and Astronautics. In late 1974, the House of Representatives voted a partial reform of its committee jurisdictions, which included a consolidation of civilian research and development in the reorganized Committtee on Science and Technology. Specifically included within this was energy research and development and environmental research and development. The Senate has no such organizational structure. This reorganization is new, and not totally accepted by Committees which lost jurisdiction. For this reason, I can empathize with the problem forcing the agencies represented here today in resolving your own jurisdictional issues.

There is another problem which has affected the smooth operations of Congressional Committees and Executive Agencies, and that is the controversial nature of many of our environmental laws and regulations. The Congress and the Executive have different views on such fundamental areas as clean air legislation, strip mining legislation, toxic substances legislation, clean water legislation, land use legislation, and energy policy. This disagreement makes it difficult to develop harmony in the ranks, especially when residual differences exist between, for example, the Department of Agriculture and the EPA on pesticide regulations.

This difference on how to proceed with regulations should not really affect the research and development activities of the agencies involved. In fact, in the area of research and development there is very little disagreement about the goals, and the importance of those goals. Except for dollar ($) levels, most major points are agreed upon.

In spite of this broad base of support for environmental research, testimony before my subcommittee, and reports of the National Academy of Sciences, the Congressional Office of Technology Assessment, the General Accounting Office, and the Congressional Research Service, among other groups, indicates that there are serious gaps and weaknesses in our current efforts. The prime complaints have dealt with the issues of interagency coordination and cooperation, as well as a failure to address medium and long term research problems.

One example of an effort to remedy this problem, which is directly relevant to the meeting here today, is the special environmentally related energy money which was requested in 1974. The Office of Management and the Budget, much to its credit, created two task forces, the King-Muir task force, and the Gage task force, which produced reports spelling out how this money should be spent among the more than a dozen agencies involved with these issues. These two reports, and the interagency cooperation and coordination which resulted from their implementation, are distinguished by their rarity. We, in the Congress, would be very pleased to see this type of approach to emerging research issues be expanded and perfected.

There still remains the need to provide adequate funding for necessary research projects. Our problem has been that until we know what is currently being spent, throughout the Federal government, we will not know what is adequate funding within a particular agency. One of my Subcommittee's thoughts on this matter is to have more medium to long-range planning done by the agencies involved with a particular issue, including plans for projected funding levels. With the availability of such plans, say on a five-year basis, we could make some determination about areas of sustained research within particular agencies, and the adequacy of funding within the government as a whole.

Personally, I would prefer to see the environmental research and development problems solved by network actions between agencies, rather than by a more authoritarian approach, such as a reorganization of the Federal research establishment, even with more clearly designated lines of command. I have a bias against such organizational solutions. I prefer to avoid bureaucratic, autocratic, and relatively inflexible organizational structures. Especially in the field of research, it seems that we can solve problems of coordination and cooperation within existing structures.

At this point I wish to digress somewhat from the focus of your conference, which implies that we must continue our exponential growth of energy use, and present some of my own views on the subject of energy use. In some respects the argument about energy growth and energy conservation has become one of "growth" versus "no growth," which is a false argument. This false argument is perpetuated by those who have something to lose if our exponential growth curves are curbed. They have every reason to fight any curbs in energy growth, but we must keep in mind that exponential curves cannot keep going up. The only questions are ones of time, and the nature of the curve after it begins to go down. The reason why we should try to level off this abnormal exponential growth of energy use is to avoid the certain catastrophe that will occur if we do not.

The Gross National Product, which is usually cited as a measure of the strength of our country, is not necessarily linked to energy use in any physical sense. We tend to forget that the GNP measures all economic activity, both that which is good and that which is bad. We could quite easily stabilize or reduce energy growth, while increasing the GNP, simply by increasing energy prices.

We could also probably increase the GNP much faster than we could energy use if we removed environmental controls, which would lead to increased medical bills, hospital use, and the costs of food by reducing agricultural productivity. My point is that the relationship of energy use to the GNP is variable, while the relationship of energy use to environmental quality is direct. The more energy we use the worse our environment will be.

What we need to do as a society is to evaluate our uses of energy, and decide if using more energy is worth it. The main reason to use more energy today is to create more consumable goods and services, together with a large, complex superstructure of society, and to generate leisure time. But we don't seem to be able to use the leisure creatively, or to escape the entangling complexities of our governments, our communities, our homes and our personal possessions. We need energy to have time to do more important things than physical labor. Yet, the more important things we do with our time is produce even more things. We seldom seem to use this leisure that we are supposedly creating by our use of energy.

The elites of our society have practiced conspicuous consumption, and the bulk of society has attempted to keep up with this mass consumption. If we are to enter a new age of energy and resource conservation, the leaders of society will need to practice a new conspicuous simplicity. One important way to move towards this new conspicuous, or creative simplicity, is through a vigorous energy conservation research, development and demonstration program.

Such a program can help show us how to accomplish our essential social goals, with the least impact on energy and material resources. In addition, this research program needs to examine the social, economic, institutional and political restraints to developing an energy and resource conscious society.

I am fairly optimistic, much more than most Congressmen, that we can hold our energy growth down far below the projections of most governmental agencies. I believe our population will level off, as will consumer demands. We are currently using 75 Quads (Quadrillion BTU's) of energy, with projections of up to 170 Quads in the year 2000. I believe we can settle for 85 Quads by the year 2000, providing we do the proper research and we work hard at it.

The reason for my optimism about reaching this goal, and I admit it sometimes wanes, is that I believe we are in one of those great periods of change in human history. We are entering, or perhaps in the United States have entered, a post-industrial era that will lead to a basically steady-state economy. Growth in society will occur in different sectors of the economy than those in which growth occured in the past. The effect of all of these changes, in energy growth, population growth, and the economy, will be to create a new set of values, and new rules by which the society will operate.

The transition to this steady-state economy will take many years, and require a great deal of solid information if we are to minimize the disruptions of the transition. One of the proposals the Congress is considering to provide this information is an energy extension service, molded after the successful agricultural extension service which was begun nearly a century ago. This new extension service would operate similarly, hopefully by using most of the existing superstructure in the field. Its mission would be to teach people how to minimize their use of energy and resources. It would strive to instill the values of ecology, and it would be able to provide technical assistance to those who need it.

As you continue your Conference on the Health, Environmental Effects and Control Technology of Energy Use, I hope that you can develop an informal means to share resources in an effective manner. I also hope that you can develop means to get the information presented here distributed to those interested persons unable to attend.

Finally, let me congratulate the organizers for your continuing effort to make governmental research and development programs work. I hope this isn't the last such meeting by the Executive Branch in the field of environmentally related energy research and development.

ERDA's ENVIRONMENTAL SAFETY PROGRAMS

Dr. James Liverman
Assistant Administrator for Environment and Safety

It is my intent in the time allotted to me to outline for you some of the underlying philosophies of ERDA's environment and safety programs and how they are being coupled to the technology options. The ERDA commitment is indicated in Figure 1. To insure that this policy is viable, we must realize that: (Figure 2).

In the creation of ERDA, the Congress tried to ensure that a responsible official of standing equal to any of the line officials shall be appointed to concern himself with environment, health, and societal issues. That individual was the Assistant Administrator for Environment and Safety.

Clearly, the AES is faced with a large and complex task, as Figure 3 indicates. I, as the AES, must overview the adequacy of environmental R&D in wastes, control technology and safety aspects for each technology. I must perform supporting biomedical and environmental R&D. This demands that I work closely with the other assistant administrators to achieve these goals. Figures 4 and 5 indicate the three major functions within the AES structure and a breakdown of the responsibilities which characterize these functions.

How do we insure that the appropriate R&D is conducted so as to give rise to a safe, clean, environmentally acceptable energy supply? There are four major matters that must be considered with regard to the development and implementation of each technology which are expressed in Figure 6.

Each of these must be considered at the appropriate time and I believe ERDA's position is that we must begin to consider these issues simultaneously with the beginning exploration of the technology and to continue this concern throughout the development of the technology. This idea is illustrated in Figure 7.

Thus, in the development of the technology, if any one of these factors indicates a problem, the technology will be slowed or not developed at all at this time -- if the technology itself is questionable, it fails early.

If the economics or other issues seem too negative, the technology can be put on the back burner for awhile.

If, however, after initial steps everything seems to go, then the technology R&D and the related environmental, health, and societal research, including addressing of the institutional issues, is accelerated. Thus, by the time the technology is to be commercialized, we will be certain within very narrow limits that no unsuspecting surprises will crop up at the last minute to make a failure of the technology because of something that was overlooked.

Because of the continuim of health, biological, and environmental concerns, it is essential that regulatory agencies become involved at a reasonably early stage to insure that the needed information to promulgate standards exists.

Note that control technology is expected to be an integral part of the development of the technology itself. Environment and Safety group and regulatory agencies provide an overview to insure the adequacy of these measures.

How do we in ERDA insure that we are linked closely enough to the development of the technology to insure that all factors are considered?

As shown in Figure 8, our strategy is basically to create an atmosphere and organization wherein people from Environment and Safety work closely enough with the technology people so that they become very familiar with the processes being developed and any associated health, environmental, and societal issues. If this interaction is effective, then it will be clear that the pace of the technology is directly related to the Environment and Safety activities, both budgetarily and programmatically. If one suffers, the whole suffers. This approach should lead to more realistic programs as shown in Figure 9. It is essential that we do this for each technology process. Thus, for Coal Conversion (Figure 10), for instance, each separate process must be examined for possible effluents and constituents that may be in the process or in the product that could have an impact.

Out of a series of such definitions for each of the technologies comes the Environment and Safety programs of ERDA, as shown in Figure 11. It has been necessary to restructure my own internal ERDA organization in order to accommodate this interactive process with each of the technology branches, developing focused programs in each of the technology areas to the degree that the Technology Assistant Administrator and I both can feel comfortable that our programs make sense.

Note in particular the MULTI-TECHOLOGY line which indicates the existence of programs whose results, in fact, are applicable to several technology areas. To the biological organism, it is of little consequence that sulfur comes from coal combustion or from geothermal wells or that heat comes from coal-fired as well as nuclear-fired boilers. This effort constitutes about 30 percent of the total budget and is scattered rather widely through all of the various processes on the left axis.

In addition, note the GENERAL SCIENCE line which is handled independently of the technology programs. General science contributes to the understanding of the basic underlying scientific mechanisms and is used to open up new options.

It is, in fact, these two parts - the multi-technology and the general science programs - that made it possible for ERDA to move rather aggressively into all of the technology areas with minimum budget increases. (Figure 12)

It does, however, become clear rather quickly that ERDA alone does not have responsibility for the total environmental and safety aspects of energy R&D. In precisely the same sense that ERDA's multi-technology programs cut across many technologies, so the programs of ERDA as well as those of EPA, HEW and others cut across many fields of endeavor - not just energy related activity. ERDA recognized this early and in connection with the mandates of the Non-Nuclear Energy R&D Act of 1974 which requires the annual submission of a National Energy R&D Plan, we determined that in the Environment and Safety area it would be necessary to compile into a meaningful format the actual R&D work going on in the United States regarding energy related environmental and health R&D. The following five (5) figures give you an idea of: Participating Agencies (Figure 13); Federal Inventory of Energy-Related Biomedical and Environmental Research -- Objectives (Figure 14); Federal Inventory of Energy-Related Biomedical and Environmental Research -- Data Format (Figure 15); Energy Technologies by Research Category (Figure 16); Fossil Energy Health Effects Research (Figure 17).

The net result of our first survey for FY 1975 indicated about $270 million was allocated for support of various agencies, with ERDA and EPA carrying the predominate share of the activity. Our request for appropriate automated data bases for people to utilize to insure that no unnecessary duplication or voids in effort occur.

In closing, let me make five points:

In demonstrating ERDA's commitment to environmental quality:

1. We will insure that from the first concept of the technology that environmental, health, societal and institutional issues are given equal consideration with the technology.
2. We will insure that our plans, policies, and R&D efforts are discussed widely with the public.
3. We will insure, through close cooperation with regulatory agencies, that adequate information of the right kinds is being derived from the Nation's R&D program to establish regulations.
4. We will cooperate fully with all the agencies to insure that whenever possible and whenever of interest to them, joint programs of mutual benefit are developed in conjunction with our technology development programs.
5. We will insure that the data bases we develop on federal R&D are accessible to all agencies equally.

Figure 1

ERDA ENVIRONMENTAL POLICY

THERE MUST BE A COMMITMENT TO:

- CREATION OF ENERGY TECHNOLOGY CHOICES THAT ARE ENVIRONMENTALLY ACCEPTABLE
- WORKING WITH INDUSTRY, GOVERNMENT (FEDERAL, STATE, LOCAL), AND PUBLIC TO HELP ENSURE THAT ENERGY SYSTEMS REMAIN ENVIRONMENTALLY, SOCIALLY, AND ECONOMICALLY ACCEPTABLE IN THE MARKET PLACE
- AN OPEN ENVIRONMENTAL IMPACT ASSESSMENT PROCESS AIMED AT DEVELOPMENT OF TECHNOLOGY ALTERNATIVES SPECIFICALLY WEIGHED TOWARD ENVIRONMENTAL PROTECTION AND ENHANCEMENT

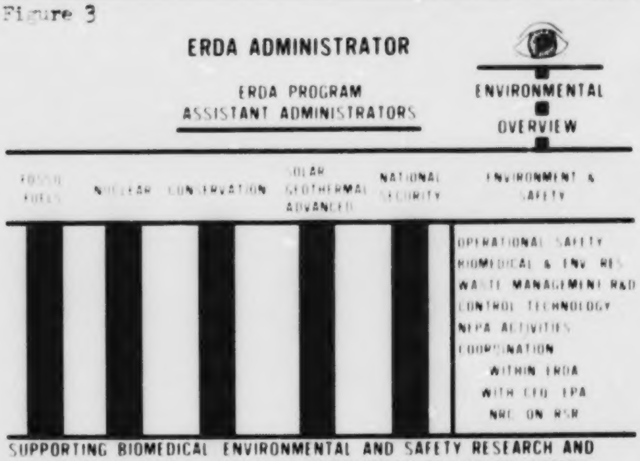
AES

Figure 2

ENVIRONMENTAL IMPLICATIONS

- NO SINGLE APPROACH CAN GUARANTEE ENVIRONMENTALLY AND SOCIALLY ACCEPTABLE COMMERCIAL ENERGY SYSTEMS.
- NO SINGLE PUBLIC OR PRIVATE AGENCY HAS CONTROL OVER THE FINAL ENVIRONMENTAL AND SOCIAL PERFORMANCE OF COMMERCIAL ENERGY SYSTEMS.
- THEREFORE ESSENTIAL THAT THE PUBLIC EIA PROCESS BE OPERATED TO INITIATE EARLY FEDERAL/STATE/LOCAL GOVERNMENTS, INDUSTRY, AND PUBLIC INTERACTION LEADING TO NEEDED INSTITUTIONAL, TECHNICAL, AND FINANCIAL RESPONSES.

Figure 3


ERDA ADMINISTRATOR
ERDA PROGRAM ASSISTANT ADMINISTRATORS
ENVIRONMENTAL OVERVIEW
FOSSIL FUELS
NUCLEAR
CONSERVATION
SOLAR GEOTHERMAL ADVANCED
NATIONAL SECURITY
ENVIRONMENT & SAFETY
OPERATIONAL SAFETY
BIOMEDICAL & ENV. RES.
WASTE MANAGEMENT R&D
CONTROL TECHNOLOGY
NEPA ACTIVITIES
COORDINATION
WITHIN ERDA
WITH CEQ, EPA
NRC ON RSR

SUPPORTING BIOMEDICAL, ENVIRONMENTAL AND SAFETY RESEARCH AND COORDINATION PROMULGATION AND ENFORCEMENT OF HEALTH, SAFETY AND ENVIRONMENTAL REGULATIONS OVERVIEW OF ADEQUACY OF R&D ON WASTES, CONTROL TECHNOLOGIES, SAFETY ASPECTS

Figure 4

ERDA'S AES FUNCTION

TO ENSURE DEVELOPMENT OF CLEAN, SAFE, PUBLICALLY ACCEPTABLE ENERGY TECHNOLOGIES – ACHIEVED THROUGH:

- RESEARCH
- OVERVIEW
- COMPLIANCE WITH REGULATORY PROCEDURE

Figure 5

AES RESPONSIBILITIES

RESEARCH

- SOCIO ECONOMIC IMPACT
- HEALTH EFFECTS
- ECOLOGICAL EFFECTS
- CHARACTERIZATION, MEASUREMENT AND MONITORING
- ENVIRONMENTAL TRANSPORT AND EFFECTS
- WASTE USE AND/OR CONTROL

OVERVIEW

- TECHNOLOGY MONITORING AND INTERACTION
- ANALYSIS AND ASSESSMENT
- COORDINATION W/STATE, FED, LOCAL
- PUBLIC DEMONSTRATION

COMPLIANCE

- EIA/EIS REVIEW AND DEVELOPMENT
- DEVELOPMENT AND COMPLIANCE WITH OTHER FEDERAL, STATE AND LOCAL REGULATIONS

AES

Figure 6

TECHNOLOGY DEVELOPMENT AND IMPLEMENTATION

- TECHNOLOGY RESEARCH AND DEVELOPMENT
- ECONOMICS OF TECHNOLOGY
- ENVIRONMENT, HEALTH, SAFETY, SOCIETAL ISSUES
- INSTITUTIONAL ISSUES

Figure 7

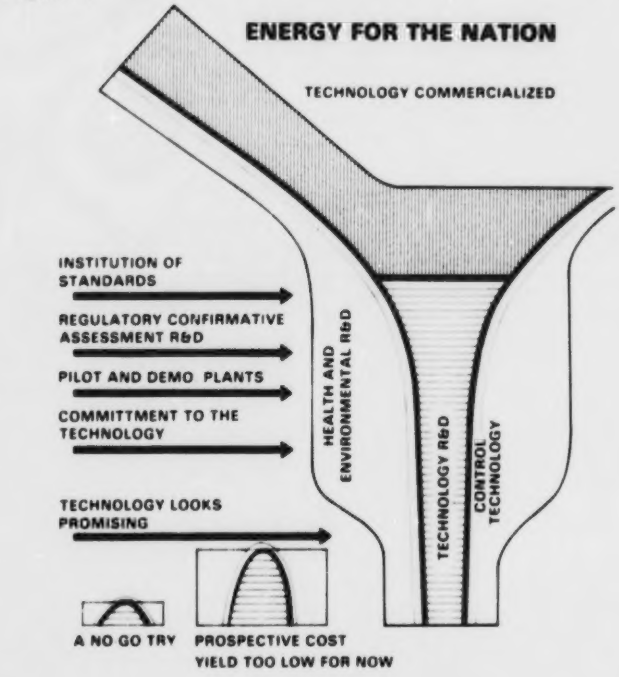

ENERGY FOR THE NATION
TECHNOLOGY COMMERCIALIZED
INSTITUTION OF STANDARDS
REGULATORY CONFIRMATIVE ASSESSMENT R&D
PILOT AND DEMO. PLANTS
COMMITTMENT TO THE TECHNOLOGY
TECHNOLOGY LOOKS PROMISING
HEALTH AND ENVIRONMENTAL R&D
TECHNOLOGY R&D
CONTROL TECHNOLOGY
A NO GO TRY
PROSPECTIVE COST YIELD TOO LOW FOR NOW

Figure 8

ERDA's ENVIRONMENTAL POLICY STRATEGY

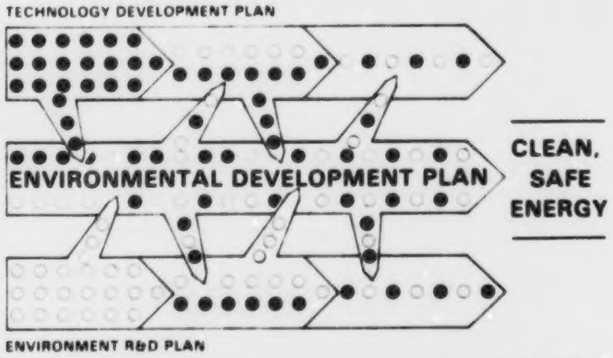
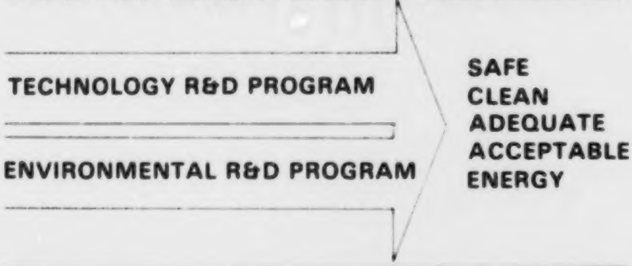

TECHNOLOGY DEVELOPMENT PLAN
ENVIRONMENTAL DEVELOPMENT PLAN
CLEAN, SAFE ENERGY
ENVIRONMENT R&D PLAN

Figure 9

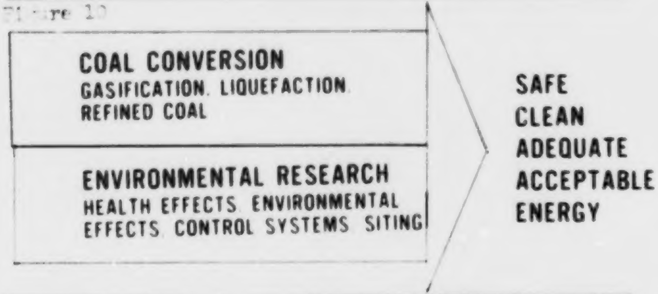
PLAN FOR SINGLE ENERGY TECHNOLOGY


TECHNOLOGY R&D PROGRAM

ENVIRONMENTAL R&D PROGRAM

SAFE
CLEAN
ADEQUATE
ACCEPTABLE
ENERGY

Figure 10


COAL CONVERSION
GASIFICATION, LIQUEFACTION, REFINED COAL

ENVIRONMENTAL RESEARCH
HEALTH EFFECTS, ENVIRONMENTAL EFFECTS, CONTROL SYSTEMS, SITING

SAFE
CLEAN
ADEQUATE
ACCEPTABLE
ENERGY

Figure 11

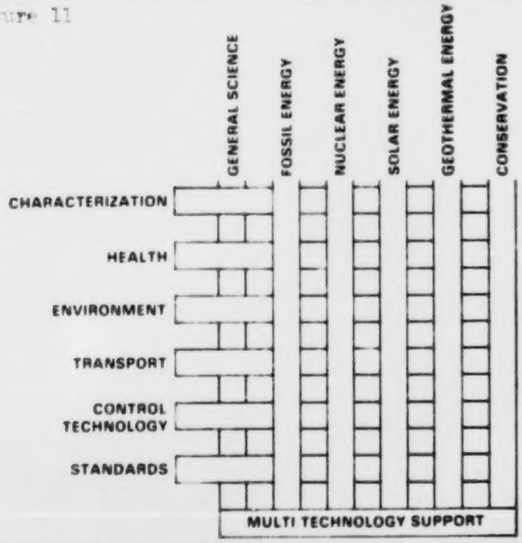

GENERAL SCIENCE
FOSSIL ENERGY
NUCLEAR ENERGY
SOLAR ENERGY
GEOTHERMAL ENERGY
CONSERVATION
CHARACTERIZATION
HEALTH
ENVIRONMENT
TRANSPORT
CONTROL TECHNOLOGY
STANDARDS
MULTI TECHNOLOGY SUPPORT

Figure 12

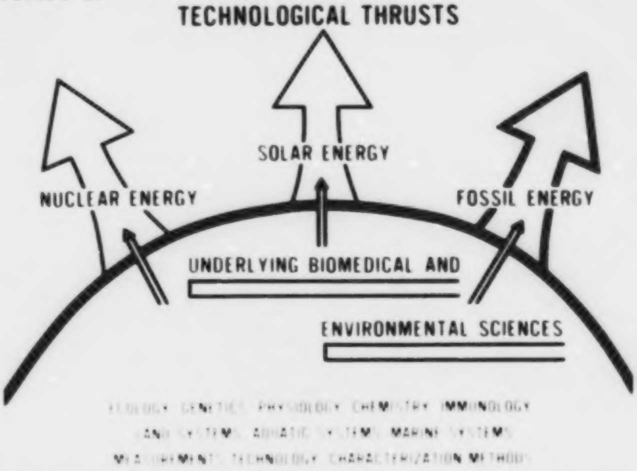

TECHNOLOGICAL THRUSTS
NUCLEAR ENERGY
SOLAR ENERGY
FOSSIL ENERGY
UNDERLYING BIOMEDICAL AND
ENVIRONMENTAL SCIENCES
ECOLOGY GENETICS PHYSIOLOGY CHEMISTRY IMMUNOLOGY
LAND SYSTEMS AQUATIC SYSTEMS MARINE SYSTEMS
MEASUREMENTS TECHNOLOGY CHARACTERIZATION METHODS

Figure 13

PARTICIPATING AGENCIES

- ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION ERDA
- ENVIRONMENTAL PROTECTION AGENCY EPA
- TENNESSEE VALLEY AUTHORITY TVA
- NATIONAL AERONAUTICS AND SPACE ADMINISTRATION NASA
- DEPARTMENT OF HEALTH EDUCATION AND WELFARE HEW
  - NATIONAL INSTITUTES OF HEALTH NIH
  - NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH NIOSH
- NATIONAL SCIENCE FOUNDATION NSF
- DEPARTMENT OF COMMERCE
  - NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION NOAA
  - OFFICE OF ENVIRONMENTAL AFFAIRS OEA
  - NATIONAL BUREAU OF STANDARDS NBS
- DEPARTMENT OF INTERIOR
  - BUREAU OF LAND MANAGEMENT BLM
  - OFFICE OF BIOLOGICAL SERVICES FISH AND WILDLIFE SERVICE OBS FWS
  - U S GEOLOGICAL SURVEY USGS
  - BUREAU OF MINES BM
  - BUREAU OF RECLAMATION BR
- DEPARTMENT OF AGICULTURE
- DEPARTMENT OF DEFENSE DOD

Figure 14

FEDERAL INVENTORY OF ENERGY-RELATED BIOMEDICAL AND ENVIRONMENTAL RESEARCH

OBJECTIVES

- PROVIDE SOURCE OF INFORMATION OF FEDERALLY FUNDED BIOMEDICAL AND ENVIRONMENTAL ENERGY RELATED RESEARCH
- PROVIDE DATA BASE TO DETERMINE EXISTING RESEARCH DEFICIENCIES AND UNDESIRABLE OVERLAP
- PROVIDE DATA BASE TO FORMULATE FUTURE RESEARCH PROGRAMS

Figure 15

FEDERAL INVENTORY OF ENERGY-RELATED BIOMEDICAL AND ENVIRONMENTAL RESEARCH

DATA FORMAT

- ORGANIZATION OF RESEARCH PROJECTS BY INTERAGENCY WORKING GROUP CATEGORIES
- BIOMEDICAL AND ENVIRONMENTAL RESEARCH CATEGORIES
  - CHARACTERIZATION MEASUREMENT AND MONITORING
  - ENVIRONMENTAL TRANSPORT PROCESSES
  - HEALTH EFFECTS
  - ECOLOGICAL EFFECTS
  - INTEGRATED ASSESSMENT
- ENERGY TECHNOLOGIES
  - COAL
  - OIL AND GAS
  - OIL SHALE
  - GEOTHERMAL
  - NUCLEAR
  - SOLAR
  - HYDROELECTRIC
  - CONSERVATION
  - MULTI TECHNOLOGY
  - GENERAL SCIENCE

Figure 16

ENERGY TECHNOLOGIES BY RESEARCH CATEGORY

	FOSSIL	GEOTHERMAL	NUCLEAR	SOLAR	CONSERVATION	HYDRO	GENERAL SCIENCE
CHARACTERIZATION MEASUREMENT MONITORING							
ENVIRONMENTAL TRANSPORT							
HEALTH EFFECTS							
ECOLOGICAL EFFECT							
INTEGRATED ASSESSMENT	MULTI-TECHNOLOGY SUPPORT						

Figure 17

FOSSIL ENERGY HEALTH EFFECTS RESEARCH

OBJECTIVES	COAL EXTRACTION	COAL COMBUSTION	COAL GASIFICATION	COAL LIQUEFACTION	OIL AND GAS	OIL SHALE
HAZARDOUS AGENTS						
NEW BIO ASSAYS						
METABOLISM AND FATE						
DOSE EFFECT RELATIONSHIPS						
MECHANISMS OF INJURY AND REPAIR						

AN ENVIRONMENTAL OVERVIEW OF UNITED STATES' ENERGY FUTURES

S. J. Gage
Deputy Assistant Administrator
Energy, Minerals and Industry - U.S.EPA
Washington, D.C.

For a country as large and complex as the United States, it is unusual when new courses are charted, when major new initiatives are undertaken. The momentum of the Nation's activities is generally too great to change directions. We speak more often of bold initiatives than we apply ourselves to bringing such programs into action. But, we are now witnessing, I believe, such a shift in national mood, direction, and action.

Since both the mass and speed of our collective activities are great, the change toward energy sufficiency, resource conservation, and environmental protection is slow. The process is rather like trying to turn a heavily laden supertanker--it takes a lot of energy and a lot of room. And the turn generates a lot of creaks and groans as the entire ship is stressed.

We are now moving in a different direction than we were three years ago. We have to watch carefully, for the rate of change can be deadly slow at times, as if the ship were dead in the water. In other instances, certain changes can be dizzying.

It is my job this morning to give an overview of the environmental consequences of this new course we are on. You have already heard about the likely shape of our energy futures and have heard about the commitment to avoid many of the environmental mistakes of the past, as we attempt to mold our energy futures. I want to present a setting for what is to come during these three days of the conference. I would like to paint a backdrop for the environmental research and development activities that you will hear described. While it would be impossible for me to cover every environmental aspect of each energy fuel and technology, existing and potential, in the time I have, I will attempt to paint in broad strokes so that the distinguished speakers who follow me can enrich the picture in color and detail.

Before turning to the real and potential environmental problems associated with the major energy alternatives, I should reiterate several facts about our present and future energy consumption patterns. First, the Nation is hooked on oil and gas. As you can see in Figure 1, the bulk of our energy--over three-fourths--is supplied by petroleum and natural gas. But, as ERDA Assistant Administrator Roger LaGassie has indicated, that pattern has to change. The nagging fear that our oil and gas resources will eventually run out has become a stark reality. We have gone to the well once too often.

There is good geologic reason to believe that there is still oil and gas offshore but not enough to offset both our growing demand and the declining production from existing wells.

King Coal, which had lost control of the energy market and had become a Black Prince at best, is due to be enthroned again. Although coal supplies less than 20 % of our energy now, most experts believe that the use of coal will double, possibly even triple, before the turn of the century. In the near-term, more coal would be used for the generation of electrical power; within the next two decades, synthetic products from coal should become available to offset the significant shortfall in domestic gas and liquid fuel production.

A highly conjectural fuel production of our future energy supplies is presented in Figure 2 to illustrate the relative timing of emerging energy supplies and technologies. These curves are not meant to present a quantitative picture. At this time, the best anyone can hope to do is to present a range of energy supply scenarios. For simplicity's sake, I will use this diagram throughout the talk to give an idea of when energy supply alternatives might come into play, what the nature of the environmental threats are, and how much time we will have to develop the required environmental safeguards.

Nuclear fission reactors are already playing an increasingly large role in electrical power generation. However, their long-term viability will depend upon an adequate supply of uranium ore, adequate enrichment and fuel reprocessing capacity, and probably ultimately the availability of the breeder reactor to utilize the much more plentiful fertile uranium isotope U-238. Looming large also are questions of reactor operational safety and radioactive waste disposal.

In the intermediate term, advanced energy technologies such as solar and geothermal may play an important role, particularly in the South and Southwest. The promise of fusion also may be realized by the turn of the century.

Finally, energy conservation has to become a way of life today and tomorrow. Shifts toward smaller, more efficient automobiles, more efficient building design, and more efficient industrial processes should continue to take the edge off our energy supply problems. Conservation will not produce any new BTU's but it will delay the need for new energy by making better use of the BTU's we have available.

Now, I would like to turn to our current and future energy supply alternatives. First, I would like to discuss the nation's oil supply alternatives.

OFFSHORE OIL AND GAS OPERATIONS

Oil and gas development on the Gulf of Mexico and California Outer Continental Shelf began with exploration of nearshore shallow waters, the first offshore platform being constructed in 1897 off Santa Barbara. Fifty years later, the first platform beyond sight of land began operating off

Louisiana. Since then, the industry has continued to advance into deeper waters and, in the North Sea, into a much more hostile environment.

The offshore oil and gas industry has made substantial progress in technology and work practices since the highly publicized Santa Barbara blowout in 1969. To date, over 17,000 wells have been drilled in U.S. coastal waters, mostly in the Gulf of Mexico such as those from the platform shown in Figure 3. However, a Council on Environmental Quality study indicated frontier OCS regions would likely confront harsher conditions than had been previously faced in other United States offshore areas. For example, conditions in the Gulf of Alaska are more severe than the industry has yet experienced anywhere in the world. Consequently, the risk of environmental damage from offshore oil operations varies from area to area. The CEQ study pointed out that development of the Georges Bank off New England and of the central Baltimore Canyon would involve relatively lower environmental risk than development of the northern Baltimore Canyon, the Southeast Georgia Embayment, and the Gulf of Alaska--all higher risk areas.

Ecological impacts in the marine and coastal environments may result from both permanent and temporary stresses created by offshore oil operations. Permanent stresses result from development of harbors and construction facilities, dredging and filling operations, placement of platforms and pipelines, alteration of drainage patters, and construction of refining and petrochemical complexes. Chronic pollution by the operational discharge of brines from active fields may also be considered to be permanent since these discharges--which also contain some oil--continue and actually increase with the age of the field.

Temporary ecological impacts are generally associated with accidents such as well blowouts, loss of drilling muds, and oil spills. These accidents often occur during drilling operations but can also occur during production and transportation phases. They can be costly and destructive and can threaten human life, Red Adair and John Wayne notwithstanding. Massive oil spills can significantly reduce biological productivity within the impacted area. After a sufficient time has elapsed, the affected ecosystem will recover to a point where the normal biota and ecosystem activity are restored, although the time required may be many years.

Crude oil and natural gas liquids may be transported to shore processing facilities by pipeline, tanker, or barge. Natural gas is transported only by pipeline. All the natural gas now produced in the Gulf of Mexico and off Southern California is transported to shore by pipeline. All the oil produced off California and 97 to 98% of the Gulf oil is piped to shore. Because most of the U.S. offshore geological formations with oil and gas potential lie within 200 miles of shore, pipelines will probably continue as a preferred OCS transportation mode, although tankers may well be used for transporting oil during the early phase of the field development in areas remote from established producing fields. Production can begin earlier, particularly far offshore, if tankers are loaded from offshore moorings in or near the field. One commonly used is the single point mooring (SPM). Production has begun in the North Sea Ekofisk and Auk Fields, although the pipelines for these fields have not yet been completed. Figure 4 shows a tanker connected to a SPM in the Ekofisk Field.

Single point moorings have specifically been developed to reduce the hazards to tankers of storms and to minimize oil spills during loading. Over 100 SPM's are in use throughout the world. Because the mooring and hosing can circle the buoy, the tanker moves to head into waves, tides, and storms. The SPM thus allows a tanker to remain moored in 15 to 20 foot waves accompanied by winds and currents. These conditions could not be tolerated at a fixed mooring.

In addition to oil pollution, tankers and barges pollute with their sewage, untreated garbage, and human wastes. A tanker of 35,000 deadweight tons generates about 1000 gallons per day each of sewage and domestic waste. If they are not treated, they can significantly degrade water quality, particularly in harbors and bays.

Crude oil may be a mixture of more than a thousand different hydrocarbons, together with trace amounts of such compounds as sulfur and nitrogen. The processes used in a refinery include distillation, sulfur removal, cracking, and reforming. Process equipment in a typical refinery is shown in Figure 5. The refining process, if uncontrolled, can lead to unacceptable water and air pollution. Water residuals include dissolved solids, suspended solids, nondegradable organics, and biochemical and chemical oxygen demands. Air emissions include NOx from heaters and boilers, SOx primarily from catalytic cracking, and hydrocarbons from crude oil and product storage. The most troublesome solid wastes are oily sludges from crude oil storage which cannot be disposed of in ordinary landfills. Land use requirements may become significant if storage, loading areas, buffer zones, and room for expansion are included.

COAL

Turning next to our most abundent fuel, it is likely that coal will continue to be used in increasing quantities in direct firing of utility and industrial boilers. Four major areas--Rocky Mountain, Northern Great Plains, Interior, and Eastern--contain more than 90% of all coal resources in the Contiguous 48 States. These areas are shown in Figure 6. There are major differences between the coals in these areas in terms of the quantity, quality, depth, seam thickness, and ownership. Availability of water resources, as well as competition for surface area usage, also vary widely. The Northern Great Plains and Rocky

Mountain Coal Provinces contain approximately 70% of the U.S. coal resources and most of the nation's low sulfur coal. There are, however, large reserves of higher quality, lower sulfur coal in Appalachia, which are capable of meeting new source performance standards, although a substantial fraction requires washing to remove pyritic sulfur.

Until recently, most U.S. coal was mined underground. Surface mining, however, has been increasing for several decades, as shown in Figure 7. Both types of mining cause environmental problems. It is essential that we take every possible measure to minimize these ecological impacts as we expand both surface and underground mining.

One of the most difficult problems caused by coal mining has been acid mine drainage which results from the oxidizing of pyritic materials in the overburden above the coal seam and the leaching of the acid from the mine. Where underground mines have been breached or spoils from surface mines have not been properly covered, acidic drainage can pollute surface streams. Sometimes, it is possible to treat the water before discharging; other times not. Approximately 80% of acid mine drainage in Appalachia originates from abandoned underground coal mines and affects thousands of miles of streams in that area.

Many mining activities have imposed huge social costs on the public at large. These costs will last for years and are in the form of stream pollution, floods, landslides, sedimentation, loss of fish and wildlife habitats, nonproductive unreclaimed land, and the impairment of natural beauty. As the Nation attempts to increase domestic energy production, care must be taken not to repeat the problems which haunt this and future generations.

In Eastern surface mining operations, care must be taken to provide adequate reclamation of mined areas, including restoration to original contours and minimization of erosion during mining and revegetation phases. Much mining is done on steep slopes in Appalachia in the manner shown in Figure 8. It has only been in the last several years that integrated mining and reclamation techniques have been available so that steep slope mining could be done without severe environmental consequences. One of these methods--the "haulback" method--offers considerable promise.

The Northern Great Plains Province contains half of the remaining coal resources in the U.S. The two largest regions, Fort Union and Powder River, contain almost 1.5 trillion tons of coal, much of which is owned by the Federal government. Most of the coal within the Province is relatively low in quality, with lignite in the Fort Union region and thick deposits of sub-bituminous in the Powder River region. Although seam depth and thickness vary considerably, some beds are quite thick (50 to 100 feet) and sufficiently near the surface to allow surface mining. Water supplies are not abundant, and most of the surface water is found in the Northern Missouri River Drainage Basin. The average annual runoff amount ranges from less than 1 inch to 10 inches.

Reclamation in the West presents a serious challenge. Knowledge of reclamation procedures is inadequate. At this time, it is generally impossible to guarantee complete success of reclamation efforts. Problems of revegetating strip mine areas in the arid and semi-arid West differ drastically from those in the humid areas of the East, as shown in the photograph of a mined area in Eastern Montana in Figure 9. From the standpoint of plant growth, climatic conditions are extreme. Seventy-five percent of the area receives less than 20 inches annual precipitation available for plant growth. In addition, there are seasonal temperature variations from -60 degrees to 120 degrees F, short frost-free periods, wide variations in overburden material and lack of adequate top soil. In some cases, the saving and spreading of top soil can do more harm than good; for instance, where the calcium carbonate layer underlying much arid land soil is mixed with the nitrogen rich organic layer and the biologic carbon nitrogen balance is destroyed. The success of revegetation efforts can vary widely, with water being a key factor in any successful western reclamation program.

One of the most difficult aspects of development to cope with is the effect upon the people who live in impacted areas. The social system and culture of the Northern Great Plains is dominated by three distinct groups of people: farmers and ranchers, townspeople, and Indians. The first two groups share one culture, while the Indians have a separate, yet related, culture.

Coal development will accelerate the "boom town" phenomena that is occurring in the Northern Great Plains region. Impacts of sudden growth will be greatest on the persons and communities close to development sites. Families are crowded together in mobile homes in a strange environment. Newly arriving families, particularly the blue-collar families, seek acceptance into the community. Social cohesion suffers as alienation and emotional distress feed on each other; and crime, suicide, and alcoholism rates tend to increase. In short, the quality of life of persons, both newcomers and residents of the area, is degraded.

COAL UTILIZATION

Most of the coal used in the United States during the next two decades will be burned in steam boilers. Coal-fired steam electric boilers are primarily located east of the Mississippi, with the heaviest concentration in the industrial upper Midwest. In addition, many new coal-fired power plants are being constructed in the West, such as the new plant being constructed at Colstrip, Montana, pictured in Figure 10.

At the present time, coal provides 42% of the fuel needs of electric power generation and 21% of those for industrial process heat. In striving for the National goal of energy self-sufficiency, significantly increased amounts of coal must be burned in these applications. It is essential to have available air pollution control technology which can mitigate the environmental impact of directly using coal in boilers and furnaces pending the development of processes to convert coal to clean synthetic liquids and gases.

It has been shown that, in combination, sulfur oxides and particulate matter from power plant stack gases can increase the death rate due to chronic disease and can aggravate these diseases. In addition, they can be a causal factor in the occurrence of chronic bronchitis in children and adults.

The oxides of nitrogen lead to photochemical smog reactions. These reactions require hydrocarbon vapors, oxides of nitrogen, and sunlight. Adverse health and environmental effects include eye and respiratory irritation, production of ozone in the atmosphere, interference with visibility, and characteristic forms of vegetation damage. In concentrations of several parts per million, nitrogen dioxide can lead to a condition in experimental animals that resembles pulmonary emphysema in man.

The most convincing case for the severity of effects of air pollution, as well as for the effects of air pollution on mortality of persons who are chronically ill, has been based on the experience of the population of London during the December, 1952 air pollution disaster. During that critical two week period, deaths exceeded several hundred per day, and approached 1000 deaths on the day of maximum sulfur dioxide concentration. Total deaths from all causes exceeded the seasonal norm by nearly a factor of three.

One of the major near term objectives of the Nation's energy research and development program is to develop and demonstrate commercial viable processes for cleaning of fossil fuel combustion flue gases. The processes include those to control emissions of sulfur dioxide and its derivatives, particulates, nitrogen oxides, and hazardous materials from coal and residual oil combustion gases. Shown in Figure 11 is the successful demonstration of one scrubbing process--the MagOx process--at Boston Edison's Mystic Station.

SYNTHETIC FUELS

Several processes are now being developed to convert coal to clean burning synthetic natural gas and lower heat content power gas. Other processes are being developed for conversion of coal to low sulfur and low ash liquids or solids for non-polluting fuels. ERDA is now in the process of awarding contracts for several synthetic fuel demonstration plants, including the large COALCON synthetic fuel plant to be constructed in Southern Illinois.

The conversion processes in such a plant, however, include various operations which can release particulates and hydrocarbons into the atmosphere, and potentially hazardous chemicals to water supplies. The environmental implications of coal conversion processes are viewed in terms of primary impacts--air emissions and water effluents, the solid waste produced and the land requirements; and secondary impacts--those connected with associated industries, population shifts, employment, housing and municipal, public and commercial services. It is expected that the water effluents from a gasification plant, before treatment, will contain suspended solids, phenols, thiocynates, cyanides, ammonia, dissolved solids such as chlorides, carbonates and biocarbonates, many sulfur compounds, trace elements and tars, oils and light hydrocarbons. Potential discharge of many other pollutants and the environmental effects these discharges may cause are currently undergoing study.

Potentially hazardous substances which are suspected in coal conversion plant process streams include polynuclears such as benzo(a)pyrene, and organo-metallics such as nickel carbonyl--both are known carcinogens. The particulare emissions are especially important since carcinogenic compounds may be particulates themselves, or adsorbed on particulates which can be respired and retained in the lungs.

FLUIDIZED BED COMBUSTION

A promising technology for using coal in an environmentally acceptable manner is fluidized bed combustion--a technology under development by ERDA and private industry. Fluidized bed combustors (FBC) burn coal under closely controlled conditions, thus reducing particulates and nitrogen oxides formation and allowing for the capture of the sulfur oxides by sulfur-scavenging materials such as limestone.

Of particular concern is hot particulate cleanup, especially below five microns. The efficiency of mechanical dust collectors drops off rapidly in this range, and high temperature filters may be required to protect gas turbines and to minimize atmospheric emissions. Environmental tests of an advanced FBC system are being run on EPA's miniplant in New Jersey, shown in Figure 12.

Finally, disposal of sulfur dioxide sorbent material and ash wastes poses an environmental problem for FBC systems and adds an economic penalty to the plants. Development of a suitable regeneration scheme which produces a salable byproduct and returns sorbent to the system is needed.

OIL SHALE

The U.S. Geological Survey estimates that U.S. oil shale deposits contain more than 2 trillion barrels of oil. However, only a very small portion of these resources could be classified as reserves. About 90% of the identified oil shale resources of the U.S. are located in a single geological formation in western Colorado, Utah and Wyoming known as the Green River formation, as shown in Figure 13.

Conceptually, oil shale may be exploited in one of two ways--the oil-bearing rock can be mined and then processed (or retorted) on the surface, or the rock can be fractured and processed underground (*in situ*) and the resulting liquids withdrawn by *wells*.

Just as for many other minerals, surface mining and retorting of oil shale creates many types of residuals such as air and water pollutants as well as massive quantities of spent shale which must be disposed of on the surface.

Air pollution may be minimized if the retort towers are tightly controlled and dust emission is suppressed by water sprays. The latter may be a difficult job in such dry areas. Total control of water pollutants will require that surface runoff be directed away from the mine, that seepage be used for dust control and reclamation, and that any other contaminated water be either injected into deep wells or purified before being released. The feasibility of these controls for a commercial scale mine has not yet been demonstrated. Contamination of ground water supplies by saline mine water is a possibility, but that depends on the local geologic structures.

Disposal of solid wastes from oil shale operations can be a formidable task. For example, if a surface mine with an average overburden of 450 feet is supporting a 100,000-barrel-per-day processing operation, it will produce an average of nearly 90,000 tons of solid wastes per day--an amount that would cover 25 acres to a depth of one foot.

Runoff water from waste piles clearly constitutes a water pollution danger. Water coming off spent shale piles under a condition where runoff rate equals rainfall rate has been estimated to contain as much as 45 milligrams per liter of sulfates, carbonates, sodium, calcium, and magnesium salts. Reclamation of the waste piles remains problemmatical and a primary environmental impact of reclamation is likely to be its consumption of water. Water consumption estimates for oil shale development suggest a need for between 121,000 and 189,000 acre feet of water per year, or about 10% of the total water usage in the Colorado part of the upper Colorado River basin in 1970.

Many of the same problems exist with underground mining techniques because part of spent shale must be disposed of on the surface. Depending on the economics, possibly all of the shale would go into surface land disposal.

The *in situ* approach involves fracturing the oil shale *underground*, introducing heat to cause pyrolysis underground, and collecting and withdrawing the shale oil through wells to the surface for upgrading. Environmental problems associated with *in situ* retorting schemes includes subsidence, air *emissions*, and disruptions of aquifers.

NUCLEAR POWER

Conventional light water fission reactors are commercially available and now represent approximately eight percent of the Nation's electrical generating capacity. Reactors, such as Niagara Mohawk's Nine Mile Point plant shown in Figure 14, are expected to be a major source of new electrical power generating capacity for the next twenty years. Breeder reactors are being developed but their entry into commercial markets will probably not occur until the end of the century.

The major impact of uranium mining is typical of that of large surface mineral mines. Parenthetically, one of the largest uranium stripmines is in the vicinity of the large coal development areas in Eastern Wyoming. The main residuals associated with the milling process are the solid and liquid talings. All the radioactive effluents are low level emissions, about 2 to 24% of current standards.

In a nuclear fuel fabrication plant, the residuals are associated with the chemical processing steps, that is, the conversion of "yellowcake" to UO(2) to UF(6) and back to UO(2). These can be handled by conventional disposal methods.

The major pollutants from light water reactors are waste heat and radioactive emissions. For a 1000 megawatt plant operating at a 75% load factor, a 32% efficient nuclear plant would emit approximately one-third more waste heat than a 38% efficient fossil plant. Relatively minor amounts of radioactivity are released from nuclear plants.

Radioactive waste management is another unique and necessary process, and one of the most critical ones for nuclear power generation. Nuclear waste cannot be allowed to enter the environment until the radioactivity has decayed below harmful levels. Certain of these wastes must be isolated from the environment for thousands of years.

To bury the residuals (both high level and other than high level) resulting from the various steps in the fuel cycle requires approximately 0.2 acre per year per 1000 magawatt reactor. Typical quantities of residuals to be buried per 1000 megawatt LWR per year are: 114 cubic feet of solidified fission products and 72 cubic feet of cladding. The total low level waste is approximately 14,000 cubic feet per 1000 megawatt LWR. While these quantities are quite small, the high level wastes are especially dangerous and must be either committed to stable geologic structures or otherwise secured for thousands of years.

During reprocessing, the main radioactive releases into the atmosphere will be tritium and Kr-85. The main radioactive release to the water will be tritium. The exposure to the general public from these releases is expected to be indistinguishable from background.

The Breeder Reactor is under development, as I'm sure you know, by the Energy Research and

Development Administration. The time frame for the breeder is such that the breeder will probably not, even if everything goes well in the demonstration program, have a commercial impact before the turn of the century. In other words, we have many years to understand and compensate for any unique problems associated with the breeder. Of course, the required research will build on over 30 years of intensive radiation biology experimentation sponsored primarily by the former Atomic Energy Commission and now carried on by ERDA and the new Nuclear Regulatory Commission.

GEOTHERMAL

Generation of electricity from geothermal steam resources occurred for the first time in 1904 in Larderello, Italy. The only commercial geothermal production in the U.S. is the Geysers area of California and dates from about 1960.

There are three basic sources of geothermal energy: natural steam, hot water, and hot dry rock. To date, geothermal steam has been used mainly to generate electricity, such as in the Geysers field in Northern California shown in Figure 15. Hot water has been largely employed for heating purposes in a few locations. Technologies for hot water and hot dry rock application to power generation are now being actively considered.

Geothermal electricity production is distinctive in that all steps of the fuel cycle are localized at the site of the power production facility. Aside from steam transport from the wellhead to the power plant, the only transportable item is electricity.

During testing and bleeding of the wells, all the non-condensable gases contained in the steam are vented to the atmosphere. Hydrogen sulfide, reaching concentrations of 500 ppm in the steam, is the principal air pollutant of concern because of toxicity and nuisance odor. Mercury and radon gas occur in geothermal steam in trace amounts. Since methyl mercury accumulates in the food chains, monitoring of the mercury pathway after emission is needed. Radon is a natural radioactive material and could build up in the environment of geothermal facilities. The environmental impact of the mercury and radon emissions is not known.

A typical geothermal brine in the Imperial Valley consists of 250,000 ppm dissolved solids--primarily silicon, calcium carbonate, sodium chloride, boron, ammonia, and argon. Because the nature of these materials and their concentrations preclude release in surface or ground water, the brine generally must be reinjected into the formation from which it was extracted. As an indication of the magnitude of this problem, disposal of an estimated 50 billion gallons of brine per year containing 50 million tons of solids would be required for a 1,000 Mwe plant in the Imperial Valley. Reinjection of the waste water, in addition to economic and environmental advantages over other disposal methods, may have the added effects of preventing land subsidence and facilitating greater steam production. Other problems include noise, ground water contamination, land use problems, ground motion, and the general problem of heat disposal. This latter item also relates to other thermal cycles.

SOLAR ENERGY

Solar heating and cooling of buildings will, in my estimation, become very important in the near-term. Nearly everyone, especially those with environmental interests applaud the much expanded solar R&D program sponsored by ERDA. It's hard to say anything bad about such uses of solar energy. So, in the interests of brevity, let me suggest that the worst environmental impact associated with solar energy that I'm familiar with is sunburn, which just emphasizes that too much of a good thing may lead to bad results.

CONCLUDING REMARKS

During this presentation, I have tried to give a balanced view of energy supply developments and their potential environmental impacts. While it may be difficult to maintain balance and objectivity at all times, I believe it is important to keep trying. In some cases, energy developers may be very vocal in their demands that environmental restrictions be set aside; in other instances, environmental advocates may be shrill in their attempts to delay or derail specific development proposals. However, both sides should keep in mind that the Nation's multiple objectives must be served over the long run. In a way, both sides need each other so we come out with the right reconciliation of energy and environmental goals.

I think the point can be best illustrated with a story.

A young Catholic girl, let's call her Mary O'Hara, was in love with John and he was in love with her. But, Mary confided in her mother, "John is a Baptist and very much against marrying a Catholic."

"Mary," said her mother, "let's use some salesmanship about this." "John's an intelligent lad, so talk to him about our great church. Tell him about the great beliefs, the noble saints, the wonderful cathedrals and the beauty of the Service. Now go out and give him a good selling job!"

Mary dried her eyes and went to see him. The morning after their next date, Mary was again sobbing. Her mother, comforting her, asked, "What's the matter? Didn't you sell him?"

"Sell him," sobbed Mary. "I oversold him. Now he wants to become a priest."

So, during the next few days, you may be hearing from both priests and sinners. But from my personal acquaintance with most of them, I suspect that you will be hearing about the best efforts of the Federal science and technology disciples. I believe that you, too, will judge their efforts to be among the "good works" of our age.

Figure 1

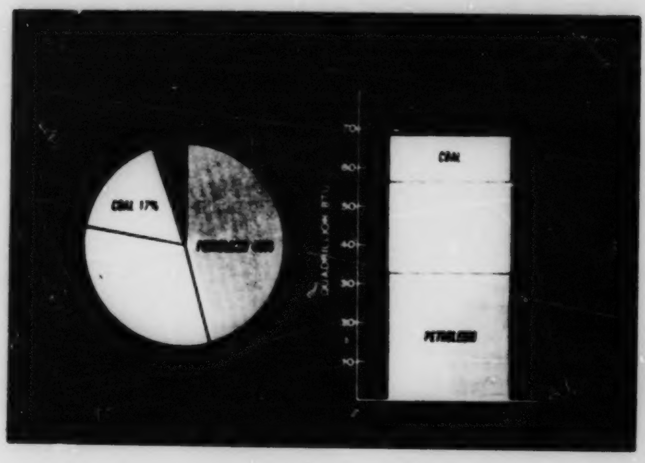


Figure 2

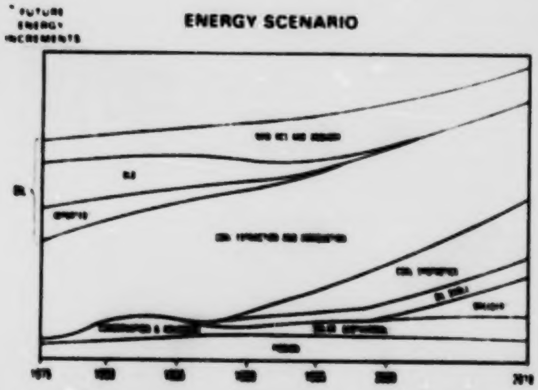


Figure 3

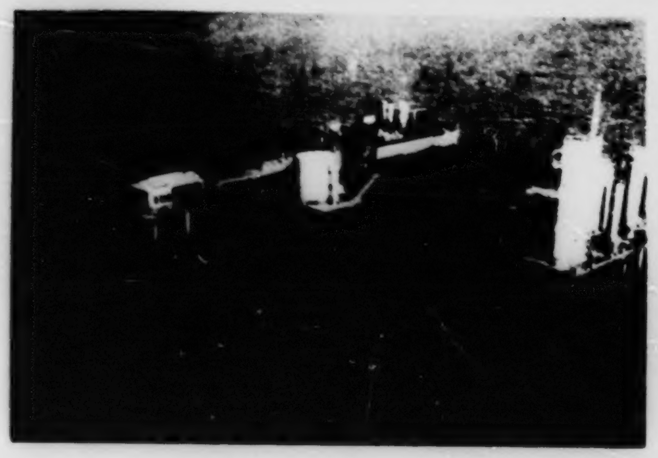


Figure 4

Figure 5

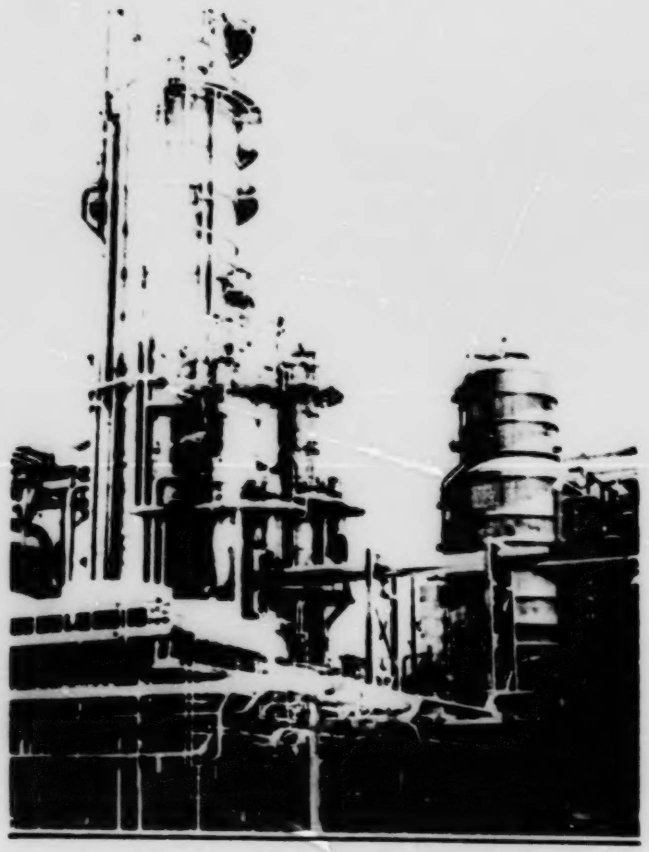


Figure 6

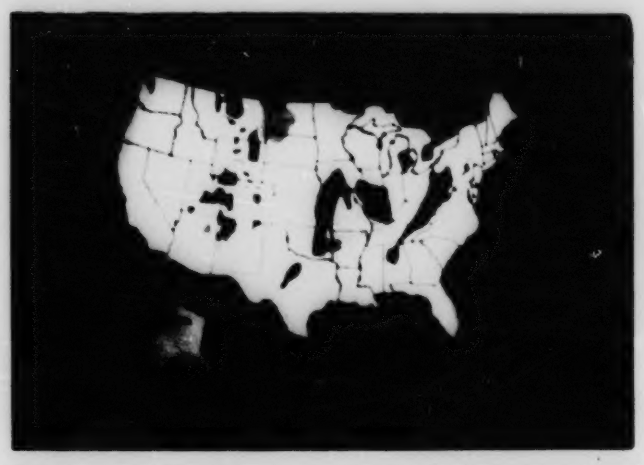


Figure 7

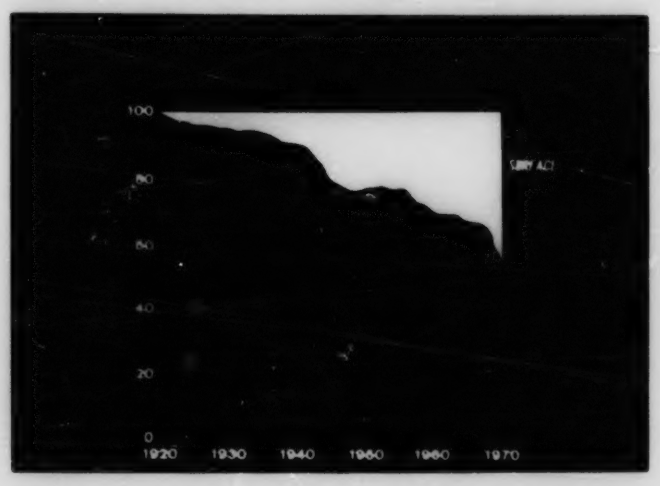


Figure 8

Figure 9

Figure 10

Figure 11

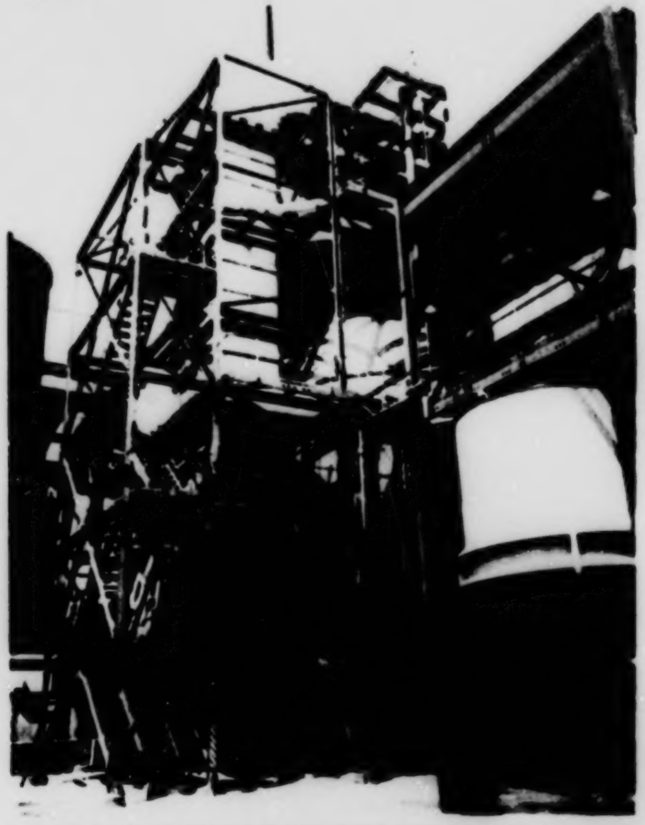


Figure 12

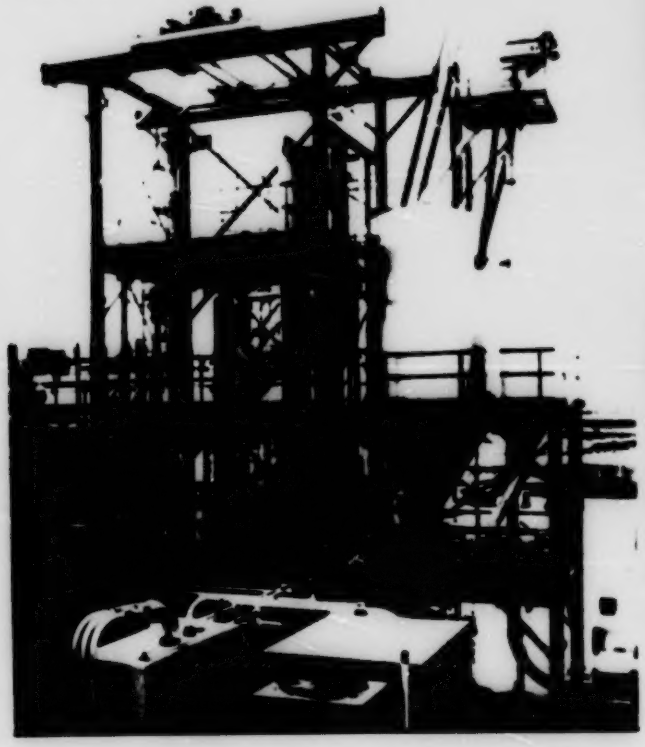


Figure 13

SOUTH DAKO
HO
WYOMING

Figure 14

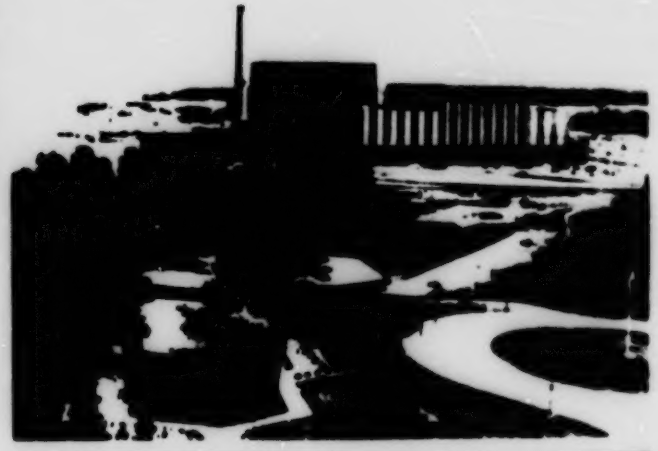


Figure 15

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CHAPTER 2
ATMOSPHERIC TRANSPORT

INTRODUCTION

Energy related pollutants are often carried from the point of emission to the point of effect by atmospheric transport. During this transport process new pollutants may be formed. Finally, the pollutants are removed from the atmosphere by a variety of wet and dry deposition processes. The pollutants produce a number of health and welfare effects during the transport process and after deposition.

The scale of interest in these effects varies enormously with regard to distances and time. Some emissions from automobile exhausts are most damaging only close to the roadway, for periods measurable in minutes. In contrast, pollutants effecting ozone in the upper atmosphere, have global ramifications which will accrue over many years.

The ability to predict the relationship between emissions and the resulting air quality is an essential ingredient in the development of cost-effective, control strategies. These relationships are also a link in the determination of the ultimate fate of the pollutant and an understanding of the final effects.

Research includes development of atmospheric models of transport, deposition and diffusion, and chemical models of transformation and removal. Extensive sampling and measurement is being conducted to develop a statistical base.

Atmospheric Transport and Transformations of Energy Related Pollutants

A. P. Altshuller
Environmental Sciences
Research Laboratory
EPA, RTP, N. C.

INTRODUCTION

Atmospheric pathways are important routes for movements of many pollutants. The scales of interest spacially and in time for such movements. can vary enormously. For example, the sulfuric acid problem associated with some types of catalytically-equipped vehicles is of concern within roadways and out to less than 100 meters from roadways. The time scale of interest is of the order of seconds to minutes. The potential impact on ozone depletion and climatic variations of fluorocarbons, other halocarbons, nitrogen oxides and related species is global in extent and the time scale involved is from 1 to over 100 years.

In between these two extremes, local, urban and regional scales of importance can be identified. The local scale is of concern with respect to fumigation by hazardous substances emitted directly from lower level industrial sources on nearby residential areas. The spacial and time scales of significance are within about 10 kilometers from the source and within 1 hour of the source. On a large urban scale of 10 to 100 kilometers and perhaps 1 to 10 hours transport time, the system of concern involves a mixture of primary and secondary (atmospherically formed) pollutants associated with combustion, vehicular and industrial sources. On a regional scale of 100 to 1000 kilometers and perhaps 10 to 100 hours of transport time, the secondary (atmospherically generated) gaseous and aerosol pollutants from large combustion sources are of the greatest concern.

The current emphasis in energy-related atmospheric transport research has been focused on the impact of increased fossil fuel combustion on transport and transformation of combustion derived pollutants on an urban-regional scale. In particular the role of sulfur oxides on the urban-regional scales of transport and transformation is receiving substantial attention. The impact of these sources on transport and transformation of nitrogen oxides and the formation of ozone in plumes also has been receiving consideration.

Experimental measurements have been made downwind of coal-fired power plants and adjacent or overlapping urban plumes. Measurements also are in progress in oil-fired power plants and on plumes from petroleum complexes. A large fraction of the available resources have been allocated to field experiments on power plant and urban plumes. However, modelling activities and laboratory simulation experiments also are being supported currently to provide as complete an assessment as possible. Other related research by the utility industry and ERDA is getting underway, but much of this activity is not yet operational.

Traditionally, the concern as to emissions from power plants has emphasized the dispersion of gaseous sulfur dioxide on a local-urban scale. Experimental measurements and dispersion modelling have led to the belief that use of tall stacks along with intermittent reductions of sulfur dioxide emissions by use of lower sulfur fuels or reduced power load will solve the sulfur oxides problem around power plants. It should be evident that the evaluation of the overall impact of the sulfur burden from combustion of fuels of higher sulfur content is much more involved. There now is ample experimental evidence that sulfate aerosols formed downwind in plumes are in the accumulation mode. The mean size for such sulfate aerosols occurs near 0.3 μm. Aerosols in this size range have lifetimes of a number of days with respect to removal processes. The transport of sulfate aerosols formed downwind in plumes has been demonstrated by direct experimentation out to several hundred kilometers. Transport of sulfate aerosols to these distances and much further is consistent with the chemical and physical properties of these aerosols in the atmosphere.

The concern about sulfate aerosols relates both to their effects in suspended form on man and animals and, when sulfate aerosols are removed in precipitation, the effect of acidity on soils, lakes and aquatic life. The amounts of acidity measured in precipitation have been consistently associated predominantly with acid sulfates both in the U. S. and in northern Europe.

Those control strategies which disperse sulfur oxides downwind do not necessarily improve regional problems. The use of lower sulfur fuels on an intermittent basis to eliminate local fumigations from a particular power plant have not been shown to be of benefit on a regional scale. It certainly is unlikely that such strategies can reduce exposures over longer averaging times on a regional scale to man, animals, soil or aquatic life. Whether intermittent control techniques will reduce exposures during regional scale episodes also has not been evaluated.

The use of continual removal techniques by application of scrubber technology or continuing use of lower sulfur fuels has been the subject of much current discussion. The resolution of the differences of opinion so often voiced depend to a substantial degree on well designed, executed and analyzed field experiments on the transport and transformation of sulfur dioxide and sulfate. Such studies can provide the Administrator of EPA and other policy-making officials with scientifically defensible answers to these critical regional problems.

PROJECT MISTT

1. Technical Discussion

The following results have been obtained in the course of summer period studies in the Missouri-Illinois area:

(1) Very little conversion of sulfur dioxide occurs within the first 10 kilometers or first hour of plume flow. The rates of conversion increase to 1 to 2% per hour between 10 and 30 kilometers. Between 30 and 50 kilometers the rate increased to 5% per hour. The overall sulfur depletion within transport distances of 50 to 100 kilometers was small or negligible.

(2) In the power plant plumes conversion of nitric oxide to nitrogen dioxide occurred by reaction with ambient ozone mixing into the plume. The mass flow of nitrogen dioxide was equal to the decrease in the ozone mass flow within the plume volume. Ozone was depleted within the plume volume over 50 kilometer ranges.

(3) In the urban-industrial plume the 1/e decay distance for sulfur decay was 90 kilometers. These results would be consistent with rapid uptake rates of sulfur by vegetation downwind. The experiments were conducted during a summer period during which removal by forest and agricultural canopies would be favored.

(4) Within the urban-industrial plume, compared to background increments in ozone concentrations and light scattering aerosols were measured out to 160 kilometers. Ozone and light scattering aerosols were the predominant constituents in the plume at 50 kilometers and more downwind and continued to increase further above the regional background to over 100 kilometers downwind of the urban sources.

(5) The patterns of behavior with time of the nitric oxide, nitrogen dioxide, ozone, sulfur dioxide and sulfates were consistent with a homogeneous photochemical mechanism but also are not inconsistent with reaction of ozone with sulfur dioxide in droplets.

The experiments related to coal-fired power plant plumes do not indicate that conversion of sulfur dioxide to sulfate by reactions with primary emissions is of any importance. This lack of influence of trace metals or other constituents may well reflect the high particulate collection efficiences now available. Conversion of sulfur dioxide to sulfate only occurs after a delay time corresponding to the time needed to convert nitric oxide to nitrogen dioxide in the plume. As in ground level reactions and smog chamber simulation, the elimination of the suppressive effects of nitric oxide on conversion reactions is essential. The scale of distance over which sulfate formation accelerates needs additional definition. Also out to 50 kilometers depletion rather than augmentation of ozone prevails. These results indicate little positive impact of coal-fired plants on sulfates or ozone on an urban scale. It is only after travel distances associated with movement across urban areas and beyond that sulfate conversion rates become substantial. Therefore, coal-fired plumes with tall stacks are likely to impact less on ambient sulfates within the air quality control regions in which the emissions originate than adjacent or even more distant air quality control regions.

Despite considerable depletion of sulfur dioxide in urban plumes by surface removal processes, substantial formation of ozone and light scattering aerosols including sulfates are observed well downwind of the urban source. Again as for coal-fired power plant plumes, rapid formation of these secondary pollutants only occurs well downwind of the urban source so the impact will occur on communities or rural areas removed from the urban area in which the plume originates.

2. Program Discussion

The largest single component of the energy related air transport program funded by the Federal Interagency R/D program has been project MISTT. The Midwest Interstate Sulfur Transformation and Transport Project - Project MISTT - was initiated by EPA's Environmental Sciences Research Lab - RTP, in the summer of 1974 (in the St. Louis area) with support from EPA's base air transport programs. Subsequent support has come from energy funding. The purpose of this project is to measure the chemical and physical transformations of the pollutants in power plant and urban-industrial plumes. A number of papers reporting project results have been published or will be presented at the April 1976 American Chemical Society meeting in New York City.

Related experiments on coal-fired plumes are in progress with a similar array of aircraft measurement techniques as part of the TVA program on energy related pollutants.

3. Projection

The FY 76 MISTT experiments will include cold weather and night conditions. The behavior of emissions also will be examined during periods of stagnating anticyclones.

OTHER FIELD PROJECTS

The mesoscale sulfur balance project (MESO) managed by the Environmental Sciences Research Lab. - RTP of EPA involves the determination of the proportion of aerosol in ambient rural air associated with sulfates formed during long distance transport. A group of 6 to 12 measurement sites will be operated between eastern Nebraska and western Pennsylvania. Samples will be collected with 6 hour time resolution to provide diurnal variations during varying meteorological conditions and to give resolution times comparable to the trajectory calculations. Air mass movements will be computed from trajectories and the input of sulfur dioxide will be determined from emission inventory data. The project is designed to test whether successive SO_2 sources across the midwest cause an accumulation of sulfates at a rate substantially greater than overall removal rates. The measurement system is scheduled to become operational in June 1976.

The aerosol composition, effects and sources (ACES) project of EPA is concerned with the sources of urban aerosol. Measurements will include the size distribution and composition of ambient aerosols in Miami, Florida, St. Louis and Pittsburgh. The aerosol species will be associated with natural and anthropogenic sources and classified as primary or secondary. The results will be compared with emission inventories and aerosol formation and removal models.

A small EPA project has been in progress in St. Louis at RAMS sites to investigate damage to materials from energy related emissions.

Existing models for power plant plume dispersion are inadequate for predictions over rugged complex terrain. An EPA energy related project will be initiated to acquire a data base for sulfur oxides, nitrogen oxides and meteorological parameters for a large coal-fired power plant in complex terrain. The measurements will be used to develop improved predictive plume models. The Clinch River Power Plant at Carbo, Virginia in the Appalachian mountains has been selected as a site with field measurements scheduled to begin in May 1976.

A model to predict transport of sulfates from the TVA power region is being developed. The model will use an up-dated SO_2-emission inventory and air trajectories along with the regional meteorological data to predict impact on eastern urban areas of emissions from the TVA area.

LABORATORY PROJECTS

In addition to the projects discussed above, EPA and TVA are conducting a number of chamber simulation studies. The EPA projects in progress are investigating both homogeneous and heterogeneous processes for conversion of SO_2 and NO_2 to sulfates and nitrates. The TVA project is scheduled to start in January 1977.

ADDITIONAL INDUSTRY AND FEDERAL ACTIVITIES

EPA is cooperating with both the Electric Power Research Institute (EPRI) and ERDA in the planning and coordination of studies on transport and transformations of sulfur oxides.

Project SURE (Sulfur Regional Experiment) is a scaled up verison of EPA's Project MESO. However, the measurement program in MESO should be well underway before SURE is operational. Therefore, SURE should benefit from input from the MESO project.

ERDA is planning a program, MAP^{3}S (Mesoscale Area Power Production Pollution Study). This project appears to have features in common with SURE and MESO, therefore close coordination is desirable. A member of EPA's Environmental Sciences Research Laboratory-RTP scientific staff is a member of the SURE Advisory Committee.

RESOURCE ALLOCATION

Since the late 1960's, a small continuing effort has been in progress in EPA's program to develop techniques for plume measurements and conduct plume experiments. EPA's base program on sulfate formation and transport in power plant and urban plumes was greatly augmented by Interagency energy funds in FY 74 and subsequent years. The laboratory and modelling development projects continue to be funded largely from the base program. The total resource allocations since 1974 and projected through 1976 are as follows ($\$ \times 10^6$).

FY 74		FY 75		FY 76	
Base	Inter-Agency	Base	Inter-Agency	Base	Inter-Agency
0.3	0.8	0.5	2.5	0.7	1.95

CONCLUSIONS

The plume studies program funded by EPA with resources from the Federal Interagency R/D program are unique in directly measuring the flow from specific sources into adjacent regions. Both in these projects, as in MESO and ACES, a key objective is to relate specific types of emission sources to air quality on a regional scale. Continuation of such projects is essential to provide results as inputs not only to proper usage of domestic energy resources but to provide an adequate basis for determining the most effective regulatory options available.

Environmental Transport Processes

H. R. Hickey and P. A. Krenkel
Tennessee Valley Authority
Chattanooga, Tennessee

INTRODUCTION

Practical application of TVA's knowledge of the atmospheric dispersion of coal-fired steam plant effluents has extended beyond its primary expected use--the design of stacks for power plants. It has resulted in defining an option for meeting ambient SO_2 standards available for an indefinite period. This option, the controlled release of atmospheric effluent, is called the "SDEL" program (sulfur dioxide emission limitation program). While there are still uncertainties to be resolved before these control programs can be fully evaluated--the main uncertainty being long-range transport of sulfate particles and their effects on human health--the option itself would not be available without prior years of investigation. These studies have included 12 coal-fired steam plants under a variety of meteorological and topographical conditions. New studies are required to better define atmospheric chemical interactions and long-range transport of sulfate particles.

Dispersion modeling capabilities have been augmented and applied to the dispersion of radionuclides from nuclear power plants for plant design and environmental impact analysis. Predictions will be compared with actual results in the dose model verification study.

Better understanding is needed of the dispersion of thermal effluents in streams and reservoirs. This is the objective of the third environmental transport project, which will test a 3-dimensional model formulated at Louisiana State University.

For possible use in the exchange of information or coordination, the names of principal investigators, research investigators, and responsible administrators are included after the title of each task.

DISCUSSION

1. Atmospheric Transport and Transformation of Emissions from Coal-Fired Power Plants

A. Atmospheric Interaction Studies

1. Full-Scale Field Studies--O. Huff, T. L. Montgomery

The primary objective of this project is to determine the chemical interactions of constituents of atmospheric emissions from coal-fired power plants with particular emphasis on ascertaining the fluxes of sulfate, the rates of oxidation of SO_2 and the effect of particulates on these rates. Instruments are carried by aircraft to measure the fluxes of the constituents through the plume at various distances downwind. Relevant meteorological parameters, such as temperature and humidity, vertical temperature profiles, wind speed and direction, and solar radiation are measured with instruments in aircraft and at ground stations.

A field study has been completed and another is currently underway. In the completed study measurements of SO_2, NO, NO_2, O_3, HONO, toluene, total sulfur and particulates (by number) were taken across the centerline of the plume. A modified high-volume sampling system equipped with impregnated filters was used to collect samples for analysis by the sulfur isotope ratio tracer method (Brookhaven National Laboratory) in determining the rate of oxidation of SO_2 in the plume. In the current field study, airborne total sulfur, NO, NO_2, O_3, total hydrocarbons, temperature, and dew point are measured. A high-volume sampling system is used to collect particulates on special filters for mass-volume measurements. These filters will also be analyzed for sulfate deposits by flash vaporization flame photometry. Data are collected under varied power plant electrostatic precipitator efficiencies. Relevant meteorological parameters are measured at ground stations. A third field study under different meteorological conditions is planned for early spring 1976.

2. Chamber Studies--L. Stockburger III, G. W. Shannon, T. L. Montgomery

The primary objective of the chamber project is to provide data similar to that of the airborne studies under well-defined and controlled conditions to determine the individual reactions most effective in overall plume chemistry and the effects of various factors on the oxidation of SO_2. Another important objective is to determine initial plume conditions more exhaustively than compliance-oriented emission measurements permit. The chamber will use either sunlight or artificial radiation. The chamber study will allow controlled introduction of stack effluent (including particulates), simulation of exposure under varied meteorological parameters, variation of conditions needed for the identification of intermediate species involved in the course of the reactions, and also will provide important kinetic information on those reactions which proceed more rapidly under initial plume conditions. This project is in its initial phase of detailed chamber design with the first experiments planned for January 1977.

The initial experiments will compare results for tests on C_3H_6, NO_x and air, and SO_2 and air mixtures with chamber results from Battelle, Calspan, and the University of North Carolina, Chapel Hill. Then, a series of experiments on the homogeneous photooxidation of SO_2 in clean air is planned. The variables to be measured include concentrations of SO_2 and sulfates, solar radiation, light intensity, temperature, and relative humidity. The next series of experiments will provide data on the photooxidation of SO_2 in the presence of filtered and unfiltered ambient air. The variables to be measured include SO_2, NO, NO_2, O_3, hydrocarbons, sulfates, nitrates, fine particulates, solar radiation, light intensity, temperature, and relative humidity. The last series of experiments will study the photooxidation of SO_2 in filtered and unfiltered diluted stack gas. The variables to be measured will be the same as in the previous series of experiments.

B. Regional Atmospheric Transport of Coal-Fired Power Plant Emissions--V. Sharma, L. M. Reisinger, T. L. Montgomery

Coordinated efforts have been initiated between state control agencies and TVA to establish an up-to-date SO_2-emission inventory for the region. This inventory should be completed by June 1976.

Development of a conservation model describing the transport of SO_2 and the formation and transport of sulfates has been initiated. The modeling region is tentatively defined by a 500- by 800- by 10-km rectangular box centered over the Tennessee Valley watershed. Meteorological input for this model will come from TVA and NWS sources, including 12 rawinsonde sites, 8 pilot balloon sites, and 19 meteorological tower sites.

Weather patterns and air trajectories are being analyzed to determine and classify the most "typical" meteorological conditions influencing air mass movements in the region. Preliminary weather pattern analytical results show that anticyclones (high pressure) centered NE-SE of the area are the most dominating synoptic situations (31 percent) while anticyclones centered NW-NE are next in frequency of occurrence (14 percent). "Backward" trajectory frequencies for a number of large cities surrounding the Tennessee Valley region are being analyzed. These analyses are divided into 6-hour trajectory steps up to a maximum 24-hour trajectory forecast. Interesting tentative results show that air parcels originating from the model area rarely affect New York City or Washington, D.C., especially for the 6- and 12-hour forecast periods. The prevailing trajectory direction emanating from the TVA region is from the southwest to the northeast with the next prevalent direction being from the west-northwest to the east-southeast.

Isopleths of sulfate concentration are being mapped on a quarterly and annual basis for an extensive area centered on the Tennessee Valley watershed to obtain a better understanding of regional sulfate distributions.

2. Evaluation and Improvement of Models Used for Radiological Impact Assessment of Gaseous Releases from Nuclear Power Plants--J. H. Davis, W. H. Wilkie, R. L. Doty, E. A. Belvin, J. A. Oppold

Radiation exposure limits applicable to the nuclear power industry are established at levels believed to be as low as practicable consistent with current technology and societal objectives. Approval for the construction of nuclear power plants is dependent on the assurance of safe operation in compliance with these limits. Because this assurance is demonstrated by analytical methods, the validity of the models and the accuracy of assumptions are of utmost importance for the timely and economical development of nuclear power. In 1974 a plan was developed by 17 Federal agencies for a research program on effects of energy use upon human health and the environment. One identified need was for confirmation or refutation of existing models, especially those models used to describe the environmental transport of radionuclides from nuclear power plants in the atmosphere. High priority was assigned to the development of applied research programs to address that need.

TVA is conducting a comprehensive program to collect experimental data on potential doses received by persons in the vicinity of nuclear power plants. Mobile pressurized ionization chambers will be used to measure direct radiation in the vicinity of an operating nuclear power reactor. Direct radiation from reactor components and from airborne effluents will be measured. Records from these mobile and other units will be correlated with records of (1) radioactivity release rates, (2) wind speed and direction, and (3) atmospheric stability parameters.

A parametric analysis of the dispersion aspects of the radioiodine dose model will also be included. Results from the parametric studies and the experimental data collected during actually occurring combinations of release rate and meteorological conditions over an extended time period will be used to evaluate the existing atmospheric dispersion and dosimetry models. In the final phase of the research refined analytical models will be developed as indicated by the results of the initial phases. However, this project was conceived to operate in conjunction with data from other programs which are still uncertain; plans must be tailored accordingly.

Plans and Progress: Mobile pressurized ionization chambers (PIC) will be used to measure external radiation exposure levels in the vicinity of the Browns Ferry Nuclear Plant (BFNP). Direct radiation from within nuclear plant components and also from radioactivity in gaseous effluents will be measured. During periods of plant operation, data will be correlated with plant operating conditions, radioactivity release rates, and meteorological conditions Development of two computer codes using the experimental data will be required to calculate the two components of gamma radiation exposure.

The BFNP is not operating presently but is scheduled to resume operation in the first quarter of 1976. In the interim, mobile PIC's are being used to gather background radiation data at various locations around the plant.

Efforts will be made to coordinate this project with another radiation monitoring project which is in progress in the vicinity of BFNP. This particular project involves TVA, the EPA's Eastern Environmental Radiation Facility, and the Alabama Department of Public Health. Data gathered from both programs will be used to the extent possible. Currently, background radiation data are being gathered at three of the fixed-location TVA/EPA monitoring stations. The data from these locations yield additional background information, and the locations serve as reference instrument checkpoints.

The atmospheric dispersion portion of the project will involve a parametric analysis of the variables in the dispersion model which is incorporated in the radioiodine dose model. Discussions have been held with Atomic Industrial Forum personnel regarding effluent dispersion experiments which are being considered for several operating nuclear power plants. A few studies of this type have been completed and the data are available for verification of the dispersion computer codes. Work is currently underway to compare dispersion code results with various data and also with selected parametric changes. Terrain model, maximum wind speed for elevated release, and plume-rise equations appear to hold promise for making realistic improvements in the model.

Status: Delivery of the high pressure ionization chambers was delayed; however, most of the instruments have been delivered and are being performance-tested and readied for operation. As a result of the delay, background data collection has been hampered. Some background data are being gathered using a borrowed PIC and the fixed-location EPA monitors.

Actual operational data collection will start when BFNP returns to operation.

Some initial dispersion code modifications have been made. Preliminary results have been obtained using basic parametric changes in the gaseous effluent dispersion model.

Except for the uncertainties of instrument delivery and BFNP startup, activities are proceeding according to projected schedules.

3. Simulation of Thermal Dispersion and Fluid Mechanics at Critical Locations in Streams and Reservoirs--W. R. Waldrop, R. C. Farmer, R. J. Ruane, W. R. Nicholas

The purpose of this study is to augment existing efforts to collect thermal field data and to promote the development of conceptual predictive models. Existing models for reservoir water quality have been valuable for preparation and explication of environmental impact statements for proposed TVA facilities. The scope of this project will include the development of predictive analytical models, recommendations for future field or laboratory studies, and a continuing review of available data and analytical techniques.

Progress: Surface heat and momentum exchange with the atmosphere, turbulent exchange, and diffuse-river interactions are physical phenomena that control thermal effluent dispersion. These are not adequately modeled with present computer codes. Experimental data describing surface heat and momentum exchange have been reviewed, and empirical representations of such data have been selected for inclusion in our models. Initial efforts to include these data are underway. Better methods for representing turbulent exchange are known, but the running time of the model must be reduced before such improvements can be fully utilized. A more generalized model of bottom conditions is needed. Generalizing the boundary conditions on the governing model equations will also allow diffuser flow to be described. Methods of accomplishing these generalizations are being studied.

In adapting thermal effluent models to our computers both a 2-dimensional and a 3-dimensional model will be used to expedite the studies. The 2-dimensional model will serve as a test vehicle for adding new physical phenomena to the model. As new phenomena are correctly modeled in this program, they will then be added to the more comprehensive 3-dimensional model.

Status: Problems to date on this study have been of a mundane nature. Our laboratory does not yet have experience in using programs as large as these models require, nor established operating procedures for expediting such calculations. The experience and procedures are being developed rapidly. No long-term problems are expected in accomplishing the objectives planned for this research.

TRANSFORMATION AND TRANSPORT OF ENERGY-RELATED POLLUTANTS

William E. Wilson
Environmental Sciences Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

INTRODUCTION

Energy related pollutants are carried from the point of emission to the point of effect by atmospheric transport. During this transport process, new pollutants may be formed. For example, SO_2 may be converted into sulfate aerosol, and organic vapors and nitrogen oxides may undergo photochemical reactions to yield ozone. The primary and secondary pollutants produce a number of health and welfare effects and are removed from the atmosphere by a variety of wet and dry deposition processes. The Environmental Sciences Research Laboratory, Office of Research and Development, EPA is concerned with the meteorological processes that control dilution and transport of pollutants; the chemical and physical processes that affect transformation and removal of pollutants; welfare effects such as visibility reduction, materials damage, and climatic change; and mathematical models that relate emissions to ambient air quality.

The ability to predict relationships between emissions and ambient air quality--as influenced by physical, chemical, and meteorological parameters--is an essential ingredient in the development of cost-effective control strategies. This has become increasingly important with the realization that emissions affect not only the air quality in their immediate vicinity, but may extend their influence for hundreds of kilometers.

TECHNICAL DISCUSSION

Currently, the atmospheric transport portion of EPA's Energy Research and Development Program is largely devoted to sulfur pollutants, SO_2 and sulfate. Sulfur pollutants are being emphasized because SO_2 emissions are expected to increase substantially with the predicted increase in the use of coal, and sulfates appear to be a health problem. The sulfur program, therefore, involves studies of the primary pollutant, SO_2, and the secondary pollutant, sulfate. Both gaseous and aerosol pollutants are involved, and consideration must be given to wet and dry deposition processes. The techniques developed in this program and many of the experimental results will apply to other energy-related pollutants.

The sulfur program is also emphasized because of the need to answer a multi-billion dollar question: Are scrubbers needed to remove SO_2 from power plant stacks, or will tall stacks with supplemental controls be adequate to maintain requir ground level SO_2 concentrations and provide for adequate control of sulfur oxides? The energy related studies of ESRL are designed to provide the administrator of EPA with adequate information to give a reasonable and scientifically defensible answer to this question.

First, it is necessary to determine the source of sulfate aerosol, which is observed to be rather evenly distributed over the greater northeastern portion of the United States. The most likely hypothesis is that sulfate is formed by the atmospheric conversion of SO_2 from power plants and that the sulfate aerosol is transported over long distances. A substantial effort is being devoted to the determination of the rates and mechanisms for transformation of SO_2 to sulfate in power plant and urban plumes. Studies are made under a variety of conditions for both medium (0-100 km) and long range (0-1000 km) transport. Other hypotheses to account for sulfate, such as sampling anomalies, biogenic sources, and primary emissions, are also being examined.

If power plant SO_2 emissions, which are transformed to sulfate during long range transport, are indeed the major sources of sulfate, the next step is to develop relationships between SO_2 emission rates and ambient sulfate levels. This involves developing meteorological models of transport, deposition, and diffusion and chemical models of transformation and removal. It is of special concern to determine if control of power plant SO_2 will produce proportional control of atmospheric sulfate. If sulfate is proportional to the concentration of SO_2, i.e., if the transformation mechanisms are first order in SO_2, control of SO_2 will produce proportional control of sulfate. However, if the transformation processes do not depend on the SO_2 concentration (or depend only weakly on the SO_2 concentration), and are controlled by the concentration of ammonia, of catalytic metals, of fine aerosols, or of oxidizing gases, then SO_2 control will not produce a proportional reduction in sulfate. If 95 or 99% SO_2 removal is required before sulfate control is apparent, it may be uneconomical or unfeasible to control sulfate by this mechanism. Such considerations are critical to the establishment of cost-effective control strategies. Studies of the rates and mechanisms of SO_2 reactions in laboratory smog chambers and field studies are aimed at answering these questions.

PROGRAM DISCUSSION

Midwest Interstate Sulfur Transformation and Transport (Project MISTT)

The purpose of this program is to measure the transformations and transport of energy-related pollutants in power plant and urban plumes. This study began during the summer of 1974 with support from the Regional Air Pollution Study and the ESRL base program. Field studies have, therefore, been concentrated in the St. Louis area. The acronym MISTT was introduced when additional support was obtained from the energy program. Information from field studies conducted during summer-74 and summer-75 are now being analyzed and reported. Two papers have been submitted to Science. Six papers will be presented at the April, 1976, American Chemical Society meeting in New York City. The major accomplishments of MISTT and their significance are summarized below.

1. Accomplishments

- In contrast to earlier work (which indicated that, except at very high relative humidity, there was little or no conversion of SO_2 to sulfate in power plant plumes), consistent conversion rates for SO_2 to sulfate of several percent per hour were measured.
- In power plant plumes, NO is converted to NO_2 by reaction with ambient O_3 mixing with the plume. Conversion of SO_2 to sulfate aerosol is slow in the early stages of the plume. Measurements of sulfate and of aerosol volume demonstrate that, after NO conversion is nearly complete, the rate of conversion of SO_2 to sulfate increases.
- In urban plumes, which are well-mixed to the ground, SO_2 mass flow decreases rapidly due to ground removal by reaction with vegetation and other surfaces. The SO_2 dry deposition rates vary with vegetation and ground surface types and with time of year.
- In power plant plumes from tall stacks, the decrease in SO_2 mass flow is much lower since the plume is isolated from the ground for a longer time and the concentration of SO_2 is lower when the plume reaches the ground.
- Ozone is generated in urban plumes ten's of kilometers downwind from the urban area. The reaction times and pollutant ratios are similar to those observed in smog chamber studies of auto exhaust.
- Urban plumes have been sampled as far as 250 km from their sources and power plant plumes as far as 60 km.
- An analytical diffusion and transport model has been developed that includes the effects of stack height, first-order sulfate formation, and SO_2 dry deposition.
- A reactive plume model has been developed and used to calculate the coagulation of primary aerosol and the reaction of plume NO with ambient O_3.

2. Significance

- Tall stacks reduce ground level concentrations of SO_2 but increase sulfate aerosol concentrations by reducing surface losses of SO_2 and permitting increased reaction times.
- To determine SO_2 conversion rates in plumes, measurements must be made at longer distances or in more disperse plumes than has been the practice previously.
- Sulfate, generated from SO_2 in power plant plumes, and ozone, generated from hydrocarbons and nitrogen oxides in urban plumes, may be transported at least hundreds of kilometers and cause air pollution incidents far from the source of pollution. These air pollution problems cannot be controlled by the political unit where the air pollution impact occurs.

The FY-76 MISTT program will attempt to develop a better statistical base for plume transformations and pollutant transport. Measurements will be made during cold weather and at night. Techniques are being developed to follow a more nearly Lagrangian flight path in the plumes, i.e. to follow the same air mass as it moves downwind. Efforts will also be made to extend the spatial scale of measurements. An attempt will be made to examine pollutant behavior during stagnating anticyclone weather patterns and to sample plumes from a power plant complex.

Mesoscale Sulfur Balance Study (MESO)

The purpose of this study is to determine the fraction of aerosol, collected in ambient rural air, which may be attributed to sulfate formed during long range transport. A network of 6-12 measurement stations will be established between eastern Nebraska and western Pennsylvania and operated for a period of one year. An X-ray fluorescent technique will be used to measure sulfur and elements heavier than sodium. Air mass movements to each sampling site will be calculated (6-day back trajectories), and the input of SO_2 into each trajectory will be determined from emission inventory data. The relationship among high sulfate measurements, meteorological conditions, and SO_2 input will be examined. The results will be used in the development of a long range transport model.

The hypothesis to be tested is that as air masses move across the country they pass over successive sources of SO_2, generally large power plants. Since sulfates are only slowly removed by natural processes, a substantial buildup of sulfate can occur from repeated emissions of SO_2.

An inexpensive two-stage sampler has been designed and a prototype built. A 6-hour time resolution has been selected to give separate samples during night (low mixing depth), day (high mixing depth), morning and evening periods, and to give resolution time comparable to the trajectory calculations (every 6 hours). The sampler will run unattended for three weeks. Every three weeks the samples, collected on two 4-inch diameter filters, will be returned to the laboratory where all 168 samples can be analyzed within 6 hours. The sampler will undergo a field test in April. The 6-12 measurement sites are scheduled to start operation June 1.

Attempts are currently being made to add rain chemistry and turbidity measurements to the MESO network.

Complex Terrain Study

Emissions of SO_2 from power plants can be decreased by flue-gas cleaning or use of low sulfur fuel. However, both of these control techniques involve an economic penalty. Air quality may also be controlled by adjustment of power loads and selection of high or low sulfur fuels in accordance with the changing capacity of the atmosphere to disperse the pollutants. These techniques are known as intermittent or supplementary control systems (ICS or SCS). Such systems require operation of real-time ambient air quality monitoring and meteorological prediction services in the vicinity of the power plant.

Although there has been concern for years about the transport and diffusion of pollutants from large power plants, only a relatively small amount of pertinent, reliable aerometric data are readily available--and most of these data are for plants in relatively uncomplicated terrain. This dearth of information is particularly critical in areas of complex terrain, areas in the United States where large power plants are proliferating. In spite of these difficulties reasonably valid predictive models exist for a non-reactive pollutant, emitted from an isolated single source in flat, open terrain. However, existing models, even those with topographic input, fail to predict the special influences of rugged, complex terrain on pollutant behavior or the effects of pollutant transformation and removal on concentrations. The purpose of the complex terrain study is to develop a data base on measured concentrations of SO_2, sulfate, NO, NO_2, and meteorological variables for a large coal-fired power plant located in an area of complex terrain. This data base will then be used to develop improved predictive techniques.

A contractor has been selected and a literature survey initiated. Field measurements are scheduled to begin in May, 1976. The Clinch River Power Plant at Carbo, Virginia, in a rugged part of the Appalachian mountains, has been selected for the experimental site. Six remote stations will monitor SO_2, sulfates, NO, NO_2, and meteorological variables. Stack emissions of SO_2, NO, and NO_2 will be monitored continuously. A mobile ground station and an instrumented helicopter will also be used.

Aerosol Composition, Effects, and Sources (Project ACES)

The purpose of this study is to determine the sources of urban aerosol. Measurements of the composition and size of ambient aerosols have been made in selected cities. The aerosol components are assigned to natural and anthropogenic sources and classified as primary or secondary in nature. These results are compared with emission inventory data. New and unsuspected aerosol pollutants are sometimes observed. Models, which include aerosol removal mechanisms and secondary aerosol formation mechanisms, can be used to relate primary sources of aerosol and precursor gases to ambient aerosol concentrations. Thus, it is possible to identify those sources that need to be controlled to provide reduction in total aerosol loading or specific aerosol components.

The optical properties of the aerosol are used to infer the contribution of various sources to visibility reduction. Field studies have been performed in cooperation with EPA's Office of Air Quality Planning and Standards (OAQPS) in Miami and St. Louis and with EPA Region III in Pittsburgh. Data reports have been prepared and distributed to OAQPS personnel and their contractors. Interpretive reports are now in preparation. Of special note is the substantial amount of organic aerosol found in St. Louis during the photochemically active season.

INTERAGENCY PARTICIPATION

Tennessee Valley Authority Programs

ESRL serves as technical project coordinator for TVA studies. These studies include: measurements of sulfate formation in power plant plumes; chamber studies of sulfate formation utilizing stack gases; and the development of a long range transport model utilizing the TVA regional monitoring network.

ERDA and Industry Programs

ESRL also cooperates with the Electric Power Research Institute (EPRI) and the Energy Research and Development Administration (ERDA) in the planning and coordination of their studies of the transformation and long range transport of sulfur pollutants.

EPRI is now seeking a contractor for Project SURE (Sulfur Regional Experiment). This will be an expanded version of EPA's Project MESO (SURE's projected funding level is 20 times that of MESO) with the addition of substantial aircraft measurements. However, the MESO study will begin 6 months to a year sooner than SURE. Therefore, MESO will provide useful input into the SURE program. MESO will utilize the emission inventory being developed by EPRI for SURE.

ERDA's program, MAP^3S (Mesoscale Area Power Production Pollution Study), is less well-defined than SURE and also will not be operational until sometime in FY-77. This program will also cover the northeast. It will feature extensive use of instrumented aircraft to map pollutants.

ESRL will cooperate with these programs to the maximum extent that appears to be useful. An ESRL staff member serves on the SURE advisory panel. At least one SURE and MESO station will probably be co-located for quality control purposes.

Even though ERDA and industry are supporting a substantial effort in long range transport of sulfur pollutants, it is important for EPA to maintain a minimal program in this area. EPA's MESO differs from SURE and MAP^{3}S in that it is directed more toward an understanding of the meteorological, physical, and chemical processes that govern transformation and transport. This type of research program is needed to provide results that can be generalized and applied to other situations.

RESOURCE ALLOCATION

COS: Transport and Fate of Energy-Related Pollutants in Ecosystems
SOS: Chemical, Physical and Meteorological Studies in Energy-Related Pollutants in the Atmosphere

PE EHE 625 RTP/ESRL

Major Studies	1000$ FY75	 FY76	Status
Midwest Interstate Sulfur Transformation and Transport. Project MISTT. Study of transformation of energy-related pollutants plumes out to ∼ 250 km.	595	565	Field Studies #1 and #2 complete. Six papers to be presented at NY, ACS, 4-75. Transformation of SO_2 to sulfate aerosol and NO to NO_2 in power plant plumes documented. Formation of ozone and light scattering aerosol in urban plumes documented.
Complex Terrain. Develop and validate procedures for predicting atmospheric transport and dilution of pollutants from coal utilization by electric utilities in complex terrain.	500	350	Contractor and field site selected. Experimental phase of Project will be initiated in May.
Petroleum Complex. Study the effect of emissions of a petroleum refinery complex on oxidant transport.	115	65	Two field studies completed. Preliminary report received.
Transformation of Pollutants in Oil-fired Plumes.	185	30	Field studies underway.
Aerosol Composition, Effects, and Sources. Project ACES. Determine the fraction of primary and secondary aerosols, collected in ambient urban air, which may be attributed to energy-related sources in several cities.	215	30	Field studies completed in Miami and St. Louis (with OAQPS) and in Pittsburgh (with Region III). Data reports delivered. Interpretive reports being prepared.
Mesoscale Sulfur Balance. Determine the fraction of aerosol mass, collected in ambient rural air, which may be attributed to sulfate formed from power plant emissions during long range transport.	285	185	Field program starts June 1976. Aerosol collector designed, trajectory program operational. Stagnant air mass tracked for two weeks using airport visibility and long range trajectories.
Heterogeneous Conversion of SO_2 and NO_x to Sulfates and Nitrates.	85	85	First draft of critical review finished. New $NO_x \cdot SO_2 \cdot$surface interaction discovered. Gas-aerosol reaction studies initiated.
Homogeneous Conversion of SO_2 and NO_x to Sulfates and Nitrates.	145	125	Rate of $CH_3CO_2 + SO_2$ measured. Smog chamber studies on atmospheric chemistry from energy related activities initiated.
Chemical Characterization of Model and Atmospheric Aerosols.	30	30	Model aerosols examined for organic sulfur. Collection and analysis of organic aerosols in St. Louis planned.
Damage to Materials by Energy Related Emissions.	40	35	Exposure study initiated in St. Louis at 25 RAMS sites. Damage varies with site.

DISCUSSIONS TO ATMOSPHERIC TRANSPORT SESSION

Question: Does the fact that the panel discussed only sulfur oxides and sulfates mean that sulfuric acid is not a problem?

Panel Response: Most of the measurement techniques that were employed did not differentiate sulfuric acid from other sulfates. However, there are some measurements of sulfuric acid. Another panel member added: no sulfuric acid measurements were made with the aircraft used to obtain the other measurements. A thermal technique used during ground measurements did differentiate between sulfuric acid and ammonium sulfate and ammonium bisulfate. During a six week test program, it was found that acidic conditions occurred approximately one-third of the time. Sulfuric acid measurements in reality had been made indirectly. One method used aerosol volume change measurements and calculations with an assumption that sulfuric acid is in equilibrium with water vapor, and on other used microscope observations by comparing the morphology of aircraft sample aerosols with that of sulfuric acid aerosols.

Question: Please comment on the impact of non-degradation regulations that EPA might be initiating and any impact it may have on various neighboring regions.

Panel Response: Congress is now considering this aspect in the Clean Air Act Amendments. The present concepts of non-degradation are directed towards primary SO_2 and total suspended particulates originating within a clean region. Secondary pollutants are yet to be considered as part of the non-degradation regulations.

Question: Could the panel respond to the effect of the emissions plume on any ozone increase in the plume?

Panel Response: There is a controversy on this phenomena mentioned in a Chemical Engineering News article suggesting that SO_2 in power plant plumes, through a series of reactions, could result in ozone formation. While this mechanism has not been proved or disproved, there is substantial information to suggest that is it unnecessary. There is some information on gas-fired power plant plumes where there are no SO_2 emissions. The article suggests, however, that ozone increases in these plumes. Findings by Dr. Douglas Davis who initiated the SO_2 mechanisms indicate that there are ozone bulges or increased ozone zones in the plume when the power plant plume mixes with another source of organic vapors. Findings indicate that ozone formation in plumes is generally on the basis of classical photo-chemistry between nitrogen oxide and hydrocarbons in the plume. The plume merely adds nitrogen oxides to an existing atmosphere which has hydrocarbons in it. In other words, there are sufficient hydrocarbons in the air which mixes with the plume with the nitrogen oxides and which in turn lead to the classical photo-chemistry for the formation of ozone.

Question: Is there any work going on for sulfite removal from power plants?

Panel Response: No studies have been made on power plants with scrubbers. As plants with large scale or full scale scrubbers go operational, a selected few of such power plant scrubber systems will be tested.

Question: From a health effects standpoint, is there any data on the half-life of sulfuric acid or the individual sulfate forms from emissions at ground level?

Panel Response: There have been studies which differentiate between sulfuric acid and ammonium bisulfate or sulfate, and studies that differentiate between the acid form and the acid salt in a fully neutralized zone. Unfortunately, however, the monitoring and measuring techniques used were not reliable. A number of programs are now being planned to develop methods which can be used to differentiate the various sulfate forms. These new, more reliable techniques, will be integrated into the program just as soon as they become applicable to the operational scale field studies.

Question: Have there been any findings regarding the effect that temperature has on sulfate formations?

Panel Response: Data from Brookhaven National Laboratory on coal-fired plumes over a sufficient range of water concentration, temperature, and relative humidity indicate that it is extremely difficult to separate the role of water vapor and temperature in the formation of sulfates. However, there is a very good correlation between the sulfate conversion and the function involving temperature multiplied by relative humidity. It would appear that as both temperature and water vapor increase, there is an increase in the rate of conversion. As the above are both day-time measurements, they are probably best explained by homogeneous reactions. There is also a rapid conversion at night-time which is presumed to be heterogeneous.

Question: Newer power plants have more efficient electrostatic precipitators than older plants. Will this factor make it difficult to compare older studies with the newer studies?

Panel Response: There is a lack of data on atmospheric chemistry of transport of scrubber plumes. For example, scrubbing removes only approximately 80% of sulfur leaving 20% of the sulfur available to react. In addition, the plume is momentarily saturated with water vapor. There is very little known about the increase rate of oxidation in the plume and what occurs at or toward ground level.

Question: Are there any increases in particulate nitrate from coal-fired plumes?

Panel Response: Measurement techniques are not sufficiently sensitive to take measurements from aircraft for nitrate concentrations and chemistry in the time scale occurring in the emission plume. There are some measurements available that indicate that conversion does occur from NO to NO_2. However, it is extremely difficult even in a ground level laboratory to make measurements of nitrate or nitric acid.

Question: A slide previously shown indicated the growth of the sulfur concentration with altitude as one of the processes downwind from St. Louis. Were there observations of any such complex profiles for sulfate other than those summarized in that presentation?

Panel Response: A sulfate analysis requires several minutes to collect the sample so that type of variation with altitude for sulfate could not be obtained. However, laboratory studies using light scattering techniques indicated that a type of layering that is seen with ozone did not occur with sulfate. Additional comments indicated that about a year ago there were two government groups asked to examine possible explanations for the relatively high concentrations of sulfate found in certain monitored areas. Long-range transport of sulfate was one explanation by one group but refuted by another group. The main reason for the one group feeling that long-range transport of sulfate could not be an explanation was the feeling that plumes from power plants located in cities would be greatly diluted during the transport of up to 100 kilometers or so. At high levels of sulfate of the order of 30 micrograms per cubic meter would not be observed under those conditions. One slide of a sulfate plume shown previously indicated that the size of the plume as it starts out from the city did not increase appreciably. This means that under certain conditions, which are somewhat common, there are plumes which maintain a consistency for quite a long range, even up to 100 kilometers or more, with dilution of only a factor of 2 or so. For example, a plume from St. Louis moving into Iowa and measured for about 18 hours indicated a high concentration of approximately 60 micrograms per cubic meter. Both groups now believe that long-range transport can, under certain conditions, account for high levels of sulfate over long distances.

Question: This question referred to the previous discussion and wished an explanation for the coincidence of the increase of sulfate along with the increase of sulfur dioxide and rapid fall in sulfate measurement.

Response: This work was done in St. Louis in the summer of 1975. From the data, it appears that there was another power plant interferring with the plume which added SO_2 to the plume resulting in an increase of sulfate concentrations in the measurement.

Question: Were hydrocarbon concentrations obtained, if so, what were the concentrations with distance from the source and did they mix well with the sulfate, sulfur, ozone mixture?

Response: No, the techniques utilized were not adequate for aircraft sampling and monitoring. Improved techniques have been developed and these will be tried in the sampling program planned for the summer of 1976.

Question: Where and when will reports of a St. Louis program be published?

Panel Response: Two articles have been submitted to Science; six papers will be given at the American Chemical Society meeting in April; a large status report which documents techniques used would have been published had it not been for the sulfate problem which required an extra field trip this past fall and substantial additional time. The techniques now used are quite different than techniques used in earlier plume studies. In earlier plume studies, there was measurement of generally SO_2 to sulfate ratio or an SO_2 to some inert tracer. These were taken by flying back and forth across the plume with the result samples taken were only characteristic of the pieces of the plume that were flown through. In current studies, the aircraft flies through the plume in a vertical spiral pattern obtaining a number of measurements of the plume concentration in vertical and horizontal cuts. This is transformed into a two-dimensional concentration profile. With measurements of the wind speed and direction as a function of height, a true dimensional mass concentration profile of pollutant concentration can be reconstructed.

By calculating mass flow through the plume plus ground level sampling, the fate of the SO_2 can be ascertained and reasons for SO_2 concentration changes can be postulated. Other programs are planned to sample and characterize the same volume of air mass as it is transported downwind.

Question: Wasn't the variation of SO_2 to sulfate due to the passage of the plume over or through regions in which high hydrocarbon concentration could be expected such as from cities?

Response: As mentioned previously, hydrocarbon measurements from airplanes were unsuccessful. The program will be repeated with different techniques plus hydrocarbon sampling experts in the future. A problem with hydrocarbon sampling is that hydrocarbon emissions from coal are generally located in large communities and must contend with the nitrogen oxide emissions especially from auto exhausts. NO does inhibit the oxidation of SO_2 in that the NO appears to be the first compound oxidized and practically nothing else is converted until the NO is converted. In addition, most of these studies were accomplished over rural areas which have a fairly constant hydrocarbon concentration, so variations of SC_x with NO_x could not be obtained. Other panel members responses confirmed the lack of information on hydrocarbons and the need for additional R&D funding to better characterize hydrocarbon transport and fate.

CHAPTER 3
MEASUREMENT AND MONITORING

INTRODUCTION

The program for protection of the national environment requires the development of control technologies which will reduce the emission of pollutants resulting from development and exploitation of energy resources. Development of these control technologies must proceed in accordance with a series of strategy and priority trade-offs aimed at achieving predetermined standards. These standards, in turn, will be established to reflect understood tolerance of the environment to the ecological effects of the pollutants. Measurement and monitoring techniques are an essential factor in the process.

As an example, the provisions of the Clean Air Act Amendments of 1970 and the Federal Water Pollution Control Act of 1972 include requirements to limit the emissions of pollutants from various points of discharge such as automobile tailpipes and wastewater effluents. It is fairly obvious that such measures are required if we are to maintain our air and water in a sufficiently clean state for protection of the public health and welfare. What is not obvious is the exact extent to which it is necessary to limit individual discharges in order to reach desired purity of the whole. As long as costs rise exponentially with the degree of purification, there will be public interest in control which provides adequate protection, but no more.

There are two elements which are fundamental to such an endeavor. First, the dose-response relationships much be established so that ambient air and water quality standards can be properly set. Secondly, the relationships between pollutant concentrations at the point of discharge and at the point of human contact must be established. Accurate measurements are requisite to the determination of these relationships. These measurements, will in turn, require extensive development of new measuring devices and techniques.

Programs in the area of measurement and monitoring are directed at research and development of the necessary techniques and instrumentation.

Work in progress is characterized by its variety: water measurements to assess suspended solids and sedimentation; exotic measurement devices employing lidar, laser and satellite techniques; shipboard sampling; and the development of reference standard materials.

ENERGY RELATED RESEARCH PROGRAM IN THE PERSONAL AND ENVIRONMENTAL MEASUREMENTS PROGRAM-NIOSH

Paul A. Baron, Ph.D.
Laurence J. Doemeny, Ph.D.
National Institute for Occupational
Safety and Health
Cincinnati, Ohio

INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) is committed to the protection of the worker from harmful materials and conditions in the working environment. Toward this end, the Personal and Environmental Measurements (PEM) program in the Engineering Branch aids in accomplishing this goal by investigating methods and instrumentation used to collect and measure harmful agents in the workplace air. Three different levels of methods and instrumentation are used to effectively monitor the workplace air: personal monitors, survey instruments, and area monitors.

The Occupational Safety and Health Standards[1] require the determination of worker exposure to air contaminants. The exposure is determined for ceiling levels or for 8-hour, time-weighted average levels. NIOSH has found that the most accurate method for measuring compliance with the standards is to obtain personal, breathing zone samples which can be analyzed for specific contaminants. To obtain these personal samples, sampling systems have been devised that consist of a light-weight, self-contained pump, that is generally attached to the worker's belt, and a sampling head that contains an efficient medium for the specific type of air contaminant of concern. The sampling head is attached to the worker's clothing within his/her breathing zone. Air is drawn through the sampling medium at a measured rate and for a measured length of time. The sampling medium is then sent to an analytical laboratory for analysis to determine a worker exposure. The sampling medium typically consists of a filter for particulates and a solid sorbent tube or liquid sorbent system (impinger or bubbler) for gases and vapors and particulates.

To assess areas of contamination in the workplace, it is very useful to have portable survey instrumentation that is light-weight, accurate, agent-specific, and capable of rapid measurement of contaminant levels. These survey instruments are used by Occupational Safety and Health Administration (OSHA) inspectors to pinpoint areas of possible non-compliance for further investigation, by the employer to monitor contaminant levels and target areas to be subjected to engineering controls, and by NIOSH to evaluate problem areas, bearing on the accuracy and collection of epidemiological data, and the effectiveness of personal sampling methods.

The third monitoring method is area monitoring. This includes less portable instrumentation that has recording capabilities to determine contaminant level variation over an extended period of time at a given location. Additional possibilities for such monitors include feedback to warning devices in case of dangerous contaminant levels and to engineering and process controls to keep contaminant levels below the prescribed threshold.

TECHNICAL DISCUSSION

In response to the rising need for air monitoring instrumentation as a result of the increased emphasis on energy self sufficiency, the PEM program is using interagency funds from EPA to effect improvements in such instrumentation in energy related areas. Four projects are under way in this interagency program.

(1) Evaluation of personal sampling devices in cold environments;
(2) Development of a fibrous aerosol survey monitor;
(3) Development of a miniature gas chromatograph; and
(4) Development of a portable microwave spectrometric analyzer.

These four areas of investigation will be carried out under contract. The contracts are presently in various stages of the review and bidding process.

1. With the development of United States energy resources in sub-zero environs, such as Alaska, there is an increasing need for information relative to the current air sampling instrumentation and methodology available for industrial hygiene investigations in sub-zero weather.

   In field use, cold temperatures may alter the response of such air sampling instruments as personal sampling pumps. Some basic problems to be investigated associated with the operation of air sampling instruments in sub-zero environs are: (1) greases and oils freezing; (2) bearings freezing up; (3) piston units freezing and sticking; (4) pump diaphragms becoming brittle; (5) valves sticking; (6) decreasing battery efficiency; and (7) fatiguing of electronic components. Different air sampling instruments may encounter certain problems depending on their particular design characteristics.

Since it is necessary to use personal sampling pumps for field industrial hygiene surveys, including compliance work by OSHA, data must be obtained to establish the reliability and operating characteristics of personal sampling pumps in these sub-zero investigations. In addition, investigations will be made to pinpoint other problem areas related to sample collection and analysis under extreme conditions.

2. The assessment of occupational hazard due to fibrous aerosols has become of great importance especially in light of past experience with asbestos. In addition to asbestos, other fibrous materials such as fibrous glass, textile fibers may require methods for their detection as new occupational exposure levels are set. These fibrous materials are extremely important in energy conservation as insulators.

The Occupational Safety and Health Standards requirement to measure the exposure of workers is presently fulfilled for asbestos aerosols by collection of air samples on filters and analysis of the filters using phase contrast light microscopy. A fibrous aerosol survey instrument will be built to monitor aerosol properties related to toxicity on a continuous and real-time basis. The filter collection/light microscope analysis technique is not presently adaptable to this latter application.

Fibrous particles have a number of unique properties that can be used to indicate their presence quantitatively. Some of these properties include the aerodynamic shape factor, magnetic and electrostatic polarizability, light scattering properties and large surface area per unit mass. These and other properties of fibers can be used and combined to form the operational principles of a fibrous aerosol monitor.

The properties of fibers that seem to be related to their toxicity, especially in the case of asbestos, include the aerodynamic size, the physical dimensions, and the number concentration of the fibers. The aerodynamic size of the fibers is related to the ability of the fibers to penetrate to the lower respiratory tract. Once the fibers reach this site, the physical size of the fibers is related to the ability of the fibers to penetrate to the lower respiratory tract. Once the fibers reach this site, the physical size of the fibers impedes their removal by the ususal body elimination mechanisms. Epidemiological studies indicate that the biological response due to asbestos exposure is largely related to number concentration x exposure time, i.e., the effects are cumulative.

3. With the advent of heightened emphasis on increased production and research in the area of energy, workers may be exposed to greater levels of air contaminants and a greater variety of gases and vapors.

Currently several types of portable, direct-reading instruments are available for monitoring single contaminants. These instruments can be used to monitor large work areas to obtain a record of a contaminant concentration in a general area and also to provide a warning if dangerously high concentrations of a contaminant are encountered in this area. The major problem with these instruments is that they do not measure an individual worker's exposure, thus ignoring the worker's mobility and fluctuation in contaminant concentration around the plant. The vast majority of existing instrumentation can measure only a single contaminant at a time and so one instrument must be obtained for each contaminant to be monitored.

The purpose of this study is to look at the current state-of-the-art relative to the development of a pocket gas chromatograph designed to monitor worker exposure, to prove on paper the feasibility of such a system, and outline the necessary research to have it developed. Such an instrument may provide an alternative to present personal sampling systems and be capable of determining worker exposure to several gases at the same time.

4. The need exists for a portable gas monitor which is capable of selectively detecting several trace contaminants of a hazardous or toxic nature in air. Very few techniques are available which are based upon a physical measurement and have the required specificity and sensitivity. It is felt that microwave spectrometry is a technique which can fulfill these requirements and be used in a portable instrument. A brief description of this technique follows.

All gas phase molecules are freely rotating in an air mixture, but their rotational speeds are quantized. Because some molecules are polar, electromagnetic radiation (microwave) can interact with them at discrete frequencies to increase their rotational speeds. Collisions between the polar molecules, with air molecules and with the container walls cause the molecules to give up the added energy and return them to their original rotating speeds, but in the overall process, a net absorption of microwave radiation takes place. This absorption can be detected to indicate the presence of partiuclar kinds of molecules in a mixture with air.

This technique is highly selective for two main reasons. One is that the rotational speeds for all different types of molecules are different; therefore, the discrete frequencies of microwave radiation that they can interact with are unique.

Secondly, microwave source produces radiation monochromatically by electronic oscillations, and can be readily tuned to any discrete frequency. Thus, at low pressures, where rotational absorption lines are very narrow, this spectrometric technique has a resolution and specificity superior to almost all other detection methods.

A feasibility study by Lawrence Livermore Laboratory (LLL) of the University of California of the portable microwave rotational resonance (MMR) analyzer has been completed.[4] The factors affecting sensitivity for ten different gases and vapors were investigated and the results of these investigations indicate that an instrument can be built for the ten gases in Table I with the corresponding sensitivities. With the present state-of-the-art for such an instrument, it does not seem possible to make the prototype completely portable, i.e., battery operable. One aim of the new contract will be to make the instrument as compact, light and rugged as possible, with the view that the next generation MRR analyzer may be a completely self-contained, portable instrument.

PROJECTION

Work beyond the contract efforts in the four areas mentioned will include:

1. Further investigation into aspects of sampling gases and particulates in cold environments as deemed necessary by the initial study. There are problems with the collection of materials that undergo phase transitions from solid to liquid and liquid to gas and acquire significant vapor pressures when taken from the cold environment to the room temperature environment of the analytical laboratory.
2. The fibrous aerosol monitor will require extensive field and laboratory testing to ensure its utility as an accurate monitor of asbestos and other fibrous materials. The information gained from the contract and from in-house research may provide the impetus for other types of fiber detection instruments suited to analyzing personal samples and to area monitoring.
3. Based on indications of feasiblity in the initial study, further development and construction of a prototype miniature gas chromatograph is envisioned.
4. In addition to testing and evaluation of the instrument produced under the present contract, further work will be needed on the engineering design and packaging of the microwave resonance analyzer to reduce the size and power requirements and increase portability and utility as a field instrument.

INTERAGENCY PARTICIPATION

The majority of the energy related research in the Personal and Environmental Measurements program is being funded by Interagency energy allocations totaling $350,000 supplied by EPA. The fiber monitor is being partially funded by the Bureau of Mines. NIOSH is providing one man-year of effort during FY-76 for this energy related research.

TABLE I

THRESHOLD LIMIT VALUES OF 10 GASES AND ESTIMATED DETECTION LIMITS BY MICROWAVE SPECTROMETRIC ANALYSIS

COMPOUND	TLV (ppm)[1]	MINIMUM DETECTABLE LIMIT (ppm)[4]
Acetonitrile	40	2
Acetaldehyde	200	20
Acetone	1000	50
Ammonia	25	1
Carbonyl Sulfide	*	0.1
Ethanol	1000	25
Ethylene Oxide	50	1.5
iso-Propanol	400	50
Methanol	200	4
Propylene Oxide	100	5

*No TLV has been set

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MONITORING WESTERN ENERGY RESOURCE DEVELOPMENTS

R. K. Oser, S. C. Black, D. N. McNelis,
S. H. Melfi, G. B. Morgan

Environmental Monitoring and Support Laboratory
U.S. Environmental Protection Agency
Las Vegas, Nevada 89114

INTRODUCTION

Meeting the projected energy requirements of our nation will require expanded development of both current sources (fossil fuel, geothermal, and nuclear) and proposed sources (oil shale, tar sands, solar radiation, and tides). This expansion will not only increase the burden of known contaminants and the alteration of land and water resources, but may introduce new contaminants which have not yet been recognized as problems. It is accordingly most prudent to study each energy source to the fullest extent so that problems may be anticipated and controls instituted as early as possible in the resource development. Such studies must include collection of data on known and suspected contaminants both before and after resource development. Comparison of these levels will then indicate the environmental impact of the resource development and the effectiveness of applied pollution control measures. It will also assist in the development of new controls.

To illustrate some of the facets of the problem let us consider the development of an oil shale resource. Although oil shale strata exist elsewhere in the country, the most commercially attractive deposit is the Green River Formation of Wyoming, Utah, and Colorado. It has been estimated that 600 billion barrels of oil exist in the higher grade shale of this formation. Development of this valuable resource will not, however, be without its own set of environmental problems. The potential for water pollution is high. Salinity changes to the watershed and groundwater supply can occur from the highly saline water removed from the shale during mining and processing and from runoff from the spent shale. The increased permeability of in situ fractured shale and tailings also provides for possible trace metal and organic compound additions to scarce water resources which are required for agricultural and municipal uses. Air pollution from shale extraction and conversion also presents a problem. In-situ retorting of the shale requires detonation of conventional or nuclear explosives to fracture the formation prior to application of heat. These explosives will introduce nitro compounds or radioactive materials which may escape with the off-gases or may be collected by the oil as it drains through the rubble. External retorting will emit to the atmosphere significant amounts of particulates, SO_2, NO_x, CO, trace metals, natural radionuclides and hydrocarbons. Finally, there are land disturbance problems associated with extracting the shale and disposing of the spent shale.

These are some of the environmental problems associated with the development of just one energy resource. Other problems, such as water availability and socio-economic effects, must also be addressed. The real magnitude of the problem comes into focus when one considers the great geographic area that will require surveillance as the extraction, conversion and utilization of coal, oil shale, geothermal, offshore and onshore oil and gas, uranium, and other energy resources proceed. It is essential, however, that monitoring be done to help ensure that the expanding energy resource development is accomplished in a manner consistent with the national commitment to protect the environment.

The U.S. Environmental Protection Agency's (EPA) monitoring and measurement research and development program in the Western Energy Resource Development area is designed to obtain environmental baseline information on air, surface-water, groundwater, and soil quality. Interagency participation is stressed particularly in monitoring system design, data integration and quality assurance areas. The baseline data coupled with predictive models applicable to the specific industry and site and supplemented with data gathered over several years, will enable decision makers to assess the environmental impacts from energy resource development and related activities.

PROGRAM DISCUSSION

The basic approach to monitoring the impact of projected energy developments is relatively straightforward. A set of pollutants to be expected in the various media (air, land, water, and biological) is derived, an optimized monitoring system is designed, and appropriate cost-effective instruments and techniques are developed and applied to the measurement of the candidates. Concurrent with methods research, a comprehensive quality assurance program is designed to develop procedures for assuring the accuracy and reproducibility of measurements, as it is essential that monitoring data be scientifically valid and legally defensible.

The EPA's Environmental Monitoring and Support Laboratory in Las Vegas, Nevada (EMSL-LV) is involved in a number of projects which utilize this approach to determine the environmental impacts associated with expanded energy development in the West. Overviews of these programs are presented below.

Air Monitoring. The air monitoring program involves the development of an inventory of energy-related emission sources and of air-quality and meteorological monitoring sites in the Western United States. The EPA, other Federal, State, and industrial monitoring sites, particularly those which measure multiple air-quality and meteorological parameters, will be incorporated into this activity. Their data will be integrated and interpreted to develop an air-quality baseline, assess trends and evaluate air quality for significant deterioration. The airborne monitoring capability of the EMSL-LV will be used to complement the overall effort by developing the three-dimensional aspect of air quality phenomena, conducting intensive site-specific studies to obtain data for complex terrain and complex plume modeling and model validation, and describing plume or air parcel transport and transformation. Data collected by the Ute Research Laboratory for the EMSL-LV will complement this effort by providing information on the hazardous element distribution in air over a large geographical area of Utah, Colorado, New Mexico and Arizona.

The EMSL-LV also serves as technical project coordinator for a climate modification study being conducted by the National Oceanographic and Atmospheric Administration (NOAA). At three sites in the western area (Colstrip, Montana, the Four Corners area and northern Utah) the fraction of aerosols with cloud nucleating properties will be determined as a function of plume transport time. Particular attention is given to the production rate and nucleating properties of sulfates resulting from conversions of gaseous SO_2 to particulate sulfates. The effects of moisture, oxides of nitrogen, ammonia and heavy metals on the conversion rate are also under investigation. The EPA's Environmental Monitoring and Support Laboratory at Research Triangle Park, North Carolina, is providing quality assurance for the analytical aspects of the air monitoring program. This latter effort combined with the monitoring activities will yield a unique product: uniformly validated air-quality data for a large geographical area of the Western United States necessary to assess the impact of energy-related activities and to develop national environmental policies.

Water Quality Data Integration. The water quality program is analogous to the air monitoring effort in that data collected from existing networks of the U.S. Geological Survey (USGS), other Federal and State agencies, universities and private industry are being integrated to establish surface and ground water quality baselines for the western energy area. The data will also be used to evaluate trands, to assess the environmental impact of on-line energy-related activities and to predict the additional insult from future developments. The EPA's Environmental Monitoring and Support Laboratory at Cincinnati, Ohio, is providing the quality assurance effort to the participating analytical laboratories in support of this program. This again allows for the Agency to provide a unique product of properly and uniformly validated data and data interpretation for use in the decision process at the national level. The EMSL-LV also serves as technical project coordinator to the USGS in their surface-and ground-water monitoring and appraisal efforts in coal mining areas across the continental United States and Alaska.

Remote Sensing. The large geographical area to be monitored demands the application of techniques which are capable of providing synoptic environmental assessment with a relatively short time frame. Airborne remote sensing offers such a technique through the application of proven, operational procedures and the promise of increased utility with further refinement and on-going research and development efforts.

The primary emphasis of operational remote sensing to date has been the use of instrumentation and techniques such as photography (black and white, color, and color infrared), thermal infrared and multi-spectral scanners and laser terrain profiles (through cooperation with the National Aeronautics and Space Administration (NASA) to define an environmental baseline for the Western United States.

Through the use of both manual, photo-interpretation and automated data analysis, airborne acquired information may be used to determine or assess: (1) aerial extent of strip mining impact, (2) the efficacy of reclamation activities associated with disturbed land, (3) vegetation damage related to mining and energy conversion, (4) revegetation practices, (5) drainage patterns, and (6) impact on fresh water resources. The main objective of this effort is to develop operational aerial techniques capable of determining the success of extraction and processing site rehabilitation.

Three remote sensing techniques are being developed at the EMSL-LV which have a direct bearing on monitoring pollutants related to energy development. All use lasers as an interrogating signal and operate aiming down from airborne platforms. These techniques will be used operationally to provide environmental data on energy operations.

The first technique is the downlooking airborne LIDAR (LIght Detection And Ranging) System. The device senses and ranges aerosol concentrations beneath the airborne platform. One LIDAR system developed and constructed at the EMSL-LV, has been in use for over 2 years in studies to determine point-source plume dimensions, urban plume dimensions and mixing-layer height over large geographical areas. A second technique utilizes two pulsed lasers, operating in the infrared spectrum, which are of nearly identical frequency but bracket a particular adsorption band of a pollutant or tracer gas. The device is designed to operate from an airborne platform with the earth as a reflector. It records the integrated quantity of the selected gas beneath the aircraft. One device has been constructed for monitoring ozone with subsequent devices planned to measure SO_2 and other gaseous pollutants. This pulsed laser technique is also being developed to map tracer gases released to simulate power plant effluents prior to actual construction of the facility. The third technique under consideration is laserfluorosensing. Fluorescent signatures arising from laser illumination can be highly specific, and spectral information obtained over a period of time can yield trend data. Two uses for this technique are the remote sensing of vegetation stress and the identification of oil species released during energy extraction or conversion activities.

Radiological Pollutant Monitoring and Techniques Development. The continuing development of the breeder reactor for future energy production has caused widespread concern as to the possible environmental effects resulting from the plutonium fuel cycle. This concern may be attributed, at least in part, to the paucity of information concerning plutonium releases from plants involved in the plutonium fuel cycle and the lack of standardized methodology for monitoring plutonium in the environment.

The approach to this problem at the EMSL-LV has consisted of (1) detailed characterization of the airborne effluent from appropriate facilities involved in the plutonium fuel cycle, and (2) recommendation and collaborative testing of methods to monitor plutonium in soil, air, and water.

To date, airborne effluents have been collected in the stack of a fabrication facility during 80 days of the fabrication process of plutonium-uranium oxide fuel for the Fast Flux Test Facility (a breeder reactor). Air samples were also taken in the environs of this facility. Efforts are currently underway to quantitate and characterize plutonium and/or uranium particles in these samples. A method has been recommended for monitoring plutonium in soil and is being collaboratively tested by 11 laboratories. Methods for the monitoring of plutonium in air and water are now undergoing intensive evaluation prior to their collaborative testing.

Future activities include completing the characterizations of the samples already collected and characterizing the effluent from the Barnwell Fuel Reprocessing Plant and the Fort St. Vrain high-temperature gaseous reactor.

The EMSL-LV also serves as the EPA technical program coordinator for the following three radiological monitoring projects which are covered under Interagency Agreements:

1. Evaluation and development of models used for radiological impact assessment of gaseous releases from nuclear power plants (Tennessee Valley Authority).

2. Development of specifications for instruments, methods, and systems for measuring radioactive effluents released from uranium mills, fuel fabrication and reprocessing plants, high-temperature gas-cooled reactors, and liquid metal fast breeder reactors (Lawrence Livermore Laboratory).

3. Evaluation of state-of-the-art measurement and instrumentation techniques for monitoring plutonium and uranium particulates released from nuclear facilities (Lawrence Berkeley Laboratory).

Radiological Monitoring Quality Assurance. The Radiation Quality Assurance Program which the EMSL-LV conducts for the EPA has continually expanded its three basic programs (Calibrated Sample Distribution, Intercomparison Studies, and Methods Development and Evaluation) to meet the Agency's needs. With the advent of the Energy Program, a need for additional reference materials, cross-checks, methodology and quality assurance guidelines became evident.

One study currently in progress is concerned with the identification of potential radioactive pollutants for which quality control standards, reference materials, and procedures will be needed as a result of expanded nuclear power, fossil fuel extraction, and geothermal activities. Another project is concerned with the design and development of an improved instrument for measuring beta activity, and the preparation of quality control guidelines for technicians, analysts, and managers. Other soil reference materials, including those containing uranium-235, -238, and thorium, as well as uranium mill tailings, have been prepared for distribution to participating laboratories.

The EMSL-LV is also the technical program coordinator for two quality assurance projects covered under Interagency Agreements with the National Bureau of Standards (NBS) and the Tennessee Valley Authority (TVA), respectively. The NBS has been providing the EMSL-LV with standards containing mixed gamma emitters, which are being used in a "round-robin" study of laboratories interested in measuring alpha emissions or polonium-210. The NBS is also analyzing radium in Mancos shale which will be used by the EMSL-LV as a reference material. The TVA is developing an approach to the optimization of nuclear power surveillance programs, evaluating a least-squares technique (Alpha-M Program) to obtain qualitative and quantitative information from gamma spectroscopy, and developing a users' quality control manual.

Ground Water and Geothermal Monitoring and Techniques Development. Heavy metals, radionuclides, and other substances which are known or suspected to be toxic, carcinogenic, mutagenic, or teratogenic are contained in most energy resources. Therefore, it is necessary to develop monitoring strategies which will detect the movement of the pollutants from the resource development activities to the surface water and then to the ground water environment, to predict the amounts of these pollutants going into storage, and to apprise decision-making officials of the expected impact. The EMSL-LV has several monitoring studies currently underway which will help determine the impact of coal, oil shale, and geothermal development on the ground-water environment.

At oil shale and coal strip mining areas and at a potential geothermal development site studies are underway to identify the lithologies and aquifers, locate the recharge areas, identify possible pollutants, and develop, implement, and operate a monitoring strategy to determine the contributions of these energy developments to ground water pollution. A similar study will be conducted in an energy complex consisting of coal mining, oil and gas drilling, power generation sites, a large amount of commerce and industry, and urban and suburban populations which use a significant amount of ground water. The kinds and amounts of pollution from each of these sources will be identified and a monitoring strategy will be developed and implemented to determine the nature of ground-water pollution resulting from these activities. These strategies will be systematic approaches which can be applied to other similar areas.

RESOURCE ALLOCATIONS

When the EPA was created in 1970, the Las Vegas facility was given the responsibility for developing, testing, and optimizing methods and strategies for monitoring the condition of the environment with regard to the source, movement and fate of pollutants, and their change with time. When the EPA energy/environmental program was defined in 1974, the existing programs provided a logical base for energy-related monitoring research and development projects. Funds for energy-related projects constitute about 20% of the current EMSL-LV budget. Approximately 60% of the energy funds is used for extramural (contracts and interagency agreement) projects with the balance being used to accelerate and redirect existing inhouse capabilities.

CONCLUSION

In order for the United States to achieve energy self-sufficiency in an era of dwindling oil and gas reserves and increased national demand, it will be necessary to accelerate the development of our energy resources. It is the responsibility of the U.S. Environmental Protection Agency to develop and implement multi-media monitoring systems which can be used at the Federal, State, and local levels to help ensure that this development is in concert with the national commitment to maintain and improve environmental quality. The projects outlined in this paper describe the role of the Environmental Monitoring and Support Laboratory-Las Vegas in helping to discharge this responsibility.

NOAA's ACTIVITIES IN ENERGY RELATED MEASUREMENT AND MONITORING

Alden B. Bestul and W. Lawrence Pugh
National Oceanic and Atmospheric Administration
Rockville, Maryland

INTRODUCTION

This paper describes the activities of the National Oceanic and Atmospheric Administration (NOAA) in energy related measurement and monitoring under the Interagency Health and Ecological Effects Program of the Presidential Five-Year Energy R&D Plan. These activities are directed at developing and applying techniques and instrumentation for impact assessment measurements and continuing monitoring of environmental pollutants arising from existing and future energy related facilities. Four projects are devoted to oceanic investigations, and three to atmospheric investigations.

OCEANIC INVESTIGATIONS

Some areas of our Continental Shelf are presently undergoing intensive study. This is due in part to the impending increased usage of our Continental Shelves for the production and transportation of energy resources and the possible siting of offshore power generating plants. Critical to these and similar studies is an understanding of Continental Shelf circulatory processes; the development of underway sampling systems; and the development and use of realistic data quality assurance procedures. NOAA's oceanic measurement and monitoring projects are aimed at obtaining a better understanding of these problem areas. NOAA has four oceanic measurement and monitoring projects. The projects and the project managers are as follows:

Ocean oil spill concentration and trajectory forecast. Celso Barrientos NWS/Systems Development Office.

Underway water sampling system. Robert Etkins, NOS/Engineering Development Laboratory.

Shipboard environmental data acquisition system. Roy Wyett, NWS/Systems Development Office.

Standardized and intercalibrated techniques for marine monitoring. Robert Farland, NOS/National Oceanographic Instrumentation Center.

1. Oil Spill Concentration and Trajectory Forecast

Petroleum hydrocarbons are obiquitous in the marine environment. These hydrocarbons can be introduced inadvertently from offshore oil wells, through tanker accidents and deballasting during shipping, from natural seeps and a number of other sources. The objective of this project is to develop a numerical simulation model which can be used in real time to predict the concentrations of petroleum and its trajectory in the ocean as a function of time and space from available meteorological and oceanographic data. The model will include provisions for considering the local currents, winds, and wave fields.

Project Plan

To develop this model, the following tasks are being carried out:

Surface wind field. The surface winds are used as an input to derive surface currents, wind drag and sea-air transfer.

Three dimensional currents. The current field will be defined considering tidal and wind effects as well as bottom topography.

Direct wind drag effects. A boundary layer model will be developed to better evaluate the wind effects on floating pollutants.

Wave transport. The effects of waves on the dispersion of a surface pollutant are not well known. This task will address the "surfboarding effects" and the effects of variation in the current fields as caused by nonlinear wave properties.

Sea air pollutant transfer. Evaporation and the subsequent concentrating and altered composition of a surface pollutant are important variables that will be addressed.

Horizontal diffusion. A model will be developed to provide information on the spreading of surface pollutants in the absence of wind and waves.

Overall model integration.

Project Status

All tasks are progressing. Contact and consultations have been made with personnel at the Universities of Delaware and New York, Texas A & M, Woods Hole, Virginia Institute of Marine Science, MIT, and the Coast Guard R&D Center. To date, two proposals have been submitted, one from MIT to work on the horizontal diffusion task and the second from the University of Delaware to work on the three dimensional current task.

2. Shipboard Environmental Data Acquisition System (SEAS)

The goal of this project is the development of an automated environmental data observation system for shipboard. Upon completion, this system will have the capability to provide real-time, broad-scale monitoring of meteorological and selected oceanographic parameters from ships-of-opportunity and also from fixed platforms such as oil rigs and offshore terminals. The environmental data observed will be transmitted via satellite to the National Weather Service. This system has the capability of providing observations from oceanic areas that are data sparse and provide valuable information to all users in Continental Shelf areas who need and depend on accurate real-time marine weather forecasts, warning services and pollution transport advisories.

Program Plan

The SEAS project will be developed in two phases. The first is the development of an engineering model (SEAS-1). The primary objective of this model will be to demonstrate the practicability of using an automated system on board ship for the acquisition and communication of environmental data in an operational mode.

Incorporated into this model will be sensors to automatically observe and communicate the following environmental data: air temperature, surface pressure, wind speed and direction, sea surface temperature and surface salinity. In addition, procurement of an automated expendable bathythermograph system (XBT) and a dew point sensor is planned for later incorporation.

The second phase will be the development of a prototype system (SEAS-2). The current design plans for this model include a full sensor set multiplexed into a microprocessor for transmission and for local display aboard ship. In addition to the sensor capabilities of the SEAS-1 model, the prototype SEAS-2 will have a ship's position finding and movement (speed and direction) capability. Design plans also include the possible addition of an automated wave sensor and an expendable salinity-temperature profiling device.

Project Status

Procurement of the SEAS-1 model has been initiated and delivery is expected in June 1976. Inclusion of the dew point sensor and development of the automated XBT is expected in 4th quarter 1976. The SEAS-2 prototype is expected in April 1977 with model testing and evaluation to run until August 1977 at which time the prototype system is expected to be operational.

3. Underway Water Sampling Program

The goal of this project is the development of a shipborne dynamic scanning interactive data acquisition system whose purpose is to obtain measurements with which to determine the concentration, distribution, and transport of energy-related pollutants in the water column down to 100 meters. These pollutants include both dissolved petroleum hydrocarbons and suspended particulate matter. In addition, measurements of related physical and chemical variables such as temperature, conductivity and current velocity as a function of depth will be taken.

Program Plan

The analysis for petroleum hydrocarbons and suspended particulate matter will be done on board ship using water samples pumped through a faired cable. Design plans also include an optical sensor to measure suspended particulate matter to correlate their optical properties with their physical-chemical properties as determined in the water sample analyses.

A Doppler sonar system will be utilized to measure current and ship speed as well as the depth of the water column. The resultant data, from the water sample analyses, sensor and Doppler systems will be fed into a PDP 11/40 computer to provide near real time data.

Project Status

The system design is scheduled to be completed by March 1, 1976. The basic design for the CTD sensor system has been completed and a detailed design of electronic modules is now in process. The PDP 11/40 data processing system has been received and is now being evaluated. The technical specifications for the Doppler current/depth system has been completed and RFP documentation has been initiated. Requirements for the hydrocarbon sampling are being studied prior to the preparation of procurement specifications.

4. Standardized and Intercalibrated Techniques for Marine Monitoring

Quality marine measurements are at present the exception rather than the rule. The development and mandatory utilization of data quality assurance protocols are essential to the credibility of any environmental program. The objective of this project is to develop common techniques for the standardization and intercalibration of sampling and analytical methodologies presently in use in the marine environment.

The development of these improved standards and techniques will allow intercomparison of monitoring and assessment results and pooling of data from many different sources.

Project Plan

This project is divided into three tasks: (1) standards development, (2) investigations and (3) data logger system.

1. Standards development. To assure intercalibration and the intercomparability of data taken from different sources, the following standards are being developed:

An operational field and laboratory dissolved oxygen standard.

Transfer standard for interlaboratory calibration. A CTD System will be procured initially because it represents three measurement parameters that are of concern to most all monitoring and assessment studies.

Dynamic test standard for current meters. Current meters are currently tested and evaluated in the steady state. A dynamic standard will add a new and much needed dimension toward the accurate measurement of ocean currents.

2. Investigations. Recent increase in usage of Continental Shelf areas has correspondingly produced an influx of various in situ instruments being used to measure water quality. This is a radical change from the previous standard methods of laboratory analysis. Therefore, an initiative is underway to assess and determine if there is measurement traceability from the in situ instruments to the laboratory chemical standards.

3. Data logger. A water quality instrument data logger system is being developed to automate the collection of calibration and testing data that is compatible with computer processing.

Project Status

A contract has been awarded to design the dynamic test standard. Delivery is expected in May 1976. A contract has also been awarded on the data logger system with delivery scheduled early in FY77. In addition, an RFP has gone out on the development of the laboratory dissolved oxygen standard.

ATMOSPHERIC INVESTIGATIONS:

NOAA's atmospheric measurement and monitoring projects are concerned with: (1) Lidar and Doppler lidar measurements of pollutant particulates and their transport processes, (2) cloud and precipitation modification effects of pollutants, and (3) meteorological trajectory and removal behavior of pollutants. The lidar work is led by Dr. Vernon Derr and Dr. Ronald Schwiesow of NOAA's Wave Propagation Laboratory. The cloud and precipitation modification investigations are conducted under Dr. Rudolph Pueschel of NOAA's Atmospheric Physics and Chemistry Laboratory. The trajectory and removal project is conducted under Dr. Lester Machta, Director of NOAA's Air Resources Laboratory.

1. Lidar Measurements

At present, pollutant particulates are usually detected and analyzed by ground or airborne in situ sampling devices. Those methods are of limited usefulness because of the inability of point samples to provide representative average values of the aerosol concentration and composition, which fluctuate greatly in time and space.

Current techniques for remote sensing of pollutant particulates by laser ranging devices (lidar) offer the advantages of operating continuously over ranges of tens of kilometers and of scanning over the entire hemisphere of the sky. However, these techniques are now capable only of approximate quantitative measurements because the single parameter measured is back-scatter radiance.

The purpose of the present project is to further develop lidar techniques to obtain more definitive quantitative information on size distribution and spatial and temporal measures of concentration, as well as some general information concerning the shape of pollutant particles. This development should be possible by exploiting characteristics of multiwavelength, polarization sensitive back-scatter and absorption measurements by lidar.

A second task of this project is to develop Doppler lidar techniques to determine the velocity structure of the atmospheric boundary layer under particulate loading conditions. This is necessary to trace the motion of pollutant particulates in the boundary layer and to determine the effect of boundary layer mixing and diffusion processes on particulate pollutant transport.

1.1. Particle Characteristics:

A new dual wavelength laser transmitter with accurate polarization properties has been mounted on an existing lidar apparatus, and the dual wavelength detector has been designed and is now under construction. This equipment is planned to be put into operation in January 1976 for the measurement of stack emission versus natural aerosols in the Boulder, Colorado, area.

An investigation of the depolarization properties of man-made and natural aerosols has begun with an examination of data from Fraser and Boulder, Colorado, and from Colstrip, Montana. Man-made aerosols from hot sources, such as furnaces and automobiles, frequently approximate spherical shapes so that depolarization in back-scatter is minimal; natural aerosols such as dust (not pollen) are flat and show strong depolarization. Polarization is the first identifier being investigated; multiple wavelength scatter, differential absorption and inelastic scatter are also planned. Preliminary theoretical studies on multiple wavelength back-scatter have been made to determine the required density of wavelength relative to the size distribution of aerosols.

1.2. Velocity Structure:

Doppler lidar techniques have been developed which have been used to measure profiles of mean wind and turbulent intensity in desert, seacoast, and urban environments. Currently, equipment is operational which yields two dimensional plots of the in-plane wind component for scans having either fixed range with variable elevation or fixed elevation with variable range. The technique is shown to be an effective way of obtaining micrometeorological data for diffusion models.

Remote measurement of three dimensional winds at a point without conical scan is shown feasible by differential Doppler result recently obtained. This demonstration of differential Doppler scanning provides a technologically superior method than conical scanning for meeting task objectives on ventilation factor (product of mean height of mixing layer and velocity of flow through the mixing layer). The companion project for the urban ventilation problem, to measure the large-particle mixing depth by FM-CW lidar sounding, has been analyzed theoretically, and hardware procurement is underway.

Velocity profiles have been measured across localized atmospheric vortices of sufficient intensity to be potentially damaging. One such case has been submitted for publication in the January 1976 issue of Applied Optics on subvortex flow in a large vortex.

2. Cloud and Precipitation Modification:

The purpose of this project is to develop criteria by which to assess the impact of effluents from coal-fired power plants on local weather, especially on clouds and precipitation. Measurements of significant effluent components and products are being taken in the vicinity of power generating plants using a mobile ground laboratory and specially instrumented light aircraft and helicopters. Included are continuous and point-sample in situ measurements of concentrations of cloud condensation nuclei, ice nuclei, and Aitken nuclei and concentrations of several gases and other constituents including SO_2, NO, NO_x, O_3, and NH_3. Radiation measurements and light-scattering measurements are also being made. Laboratory analyses of aerosol deposits collected in situ on membrane filters are providing information on the size, shape, and elemental composition of power plant aerosols. The effects of the pollutants on shortwave and longwave radiation are being evaluated using the radiation and scattering measurements and calculations based on measured size distribution and elemental composition.

Three sites selected for measurements are the Colstrip, Montana, Power Plant, the Four Corners Power Plant near Farmington, New Mexico, and the Kennecott, Utah, Copper Smelter. Two field measurement projects have been conducted at both Colstrip and Farmington and one at Kennecott. Preliminary analyses of nuclei data from the Colstrip and Farmington sites strongly suggest that the power plant effluents have significant impact on local and downwind concentrations of both ice nuclei and condensation nuclei.

Farmington samples collected from the plume 20 km downwind of the power plant indicate that the greater number of particles are found in the smallest size range (0.08 to 0.04 m diameter) with concentrations about two orders of magnitude higher than typical "clean-air" values. The aerosols collected both within the outside and plume were predominantly in the form of glassy beads as contrasted with the irregularly shaped particles that are derived from natural sources.

Particle size distribution within the plume at a point about 2 hours downwind of the Four Corners' stack indicates that particle formation was proceeding at a faster rate than reduction by dispersion and agglomeration, resulting in a net increase in aerosol concentration. Particle counts (especially in the 0.2 m to 0.4 m size range) in the surrounding atmosphere were also elevated as a result of contamination by the previous day's emissions, which had been carried westward by downslope flow beneath an inversion and then carried back into the Farmington area by prevailing winds.

The Farmington aerosols contained notable occurrences of calcium, titanium, iron, and copper, in addition to the ever present aluminum and silicon. Particulate sulphur present in the air mass dominated by the power plant plume is situated preferentially in the smaller sized particles (0.2 to 0.3 m) and is likely to be in the form of soluble sulfate, thus adding to the numbers of cloud condensation nuclei. Elevated numbers of cloud nuclei were, in fact, measured in this contaminated air mass.

The aerosols collected near Colstrip were found to be rich in sulphus and zinc, and to have greater incidences of some of the heavy metals (namely, palladium, titanium, and iron) than the usual aerosol. The presence of heavy metals provides an increased likelihood of ice nucleating capability in the aerosol; the ice nucleus concentration was indeed greater than is the usual background aerosol by a factor ranging from 2 to 10. Cloud condensation nuclei concentration was also higher than expected by a factor of 2 to 4; this was probably a consequence of the relative abundance of sulphur.

3. Trajectory and Removal Meteorology:

This project is being planned in direct support of the EPA Environmental Monitoring and Support Laboratory (EMSL) in Las Vegas, Nevada, through the direct cooperation of existing NOAA personnel and EPA personnel located there. A meteorologist is being recruited by NOAA to conduct the investigation.

Techniques for establishing trajectory and removal patterns will first be investigated for SO_2 from existing industrial plants in the western United States. Existing atmospheric SO_2 data, collected mainly from such plants, will be assembled. These data are of a considerably limited nature and quality. They will be analyzed to identify the gaps which are necessary to fill for a more adequate analysis of techniques for defining trajectory and removal meteorology. The data gaps identified will be filled with supplementary data to be obtained by measurements from aircraft of the EMSL fleet. On the basis of the complete data set comprised of the existing, plus the supplementary gap-filling measurements, an analysis will be made of the trajectory and removal meteorology of the western U.S. in relation to energy activities.

Measurement and Monitoring

H. R. Hickey and P. A. Krenkel
Tennessee Valley Authority
Chattanooga, Tennessee

INTRODUCTION

TVA's responsibility for planning, designing and operating its mixed nuclear, fossil, and hydroelectric energy system necessarily entails a comprehensive program for measuring and monitoring a wide range of activities and parameters. We must have ready access to information arising from national and regional programs in agriculture, forestry, fisheries, and wildlife development, disease vector control and environmental planning.

Participation in the Federal energy research program measurement and monitoring activities will allow TVA to aid in the development of improved methodology for the types and integrity of information needed to quantify the environmental residuals and impacts of energy systems.

TVA's contribution in the measurement and monitoring activities of the energy research program will entail (1) development of methods for chemical analyses of waterborne pollutants, (2) development of improved radiological surveillance programs, and (3) development and demonstration of remote sensing techniques for monitoring environmental effects of power plant emissions.

For possible use in the exchange of information or coordination, the names of principal investigators, research investigators, and responsible administrators are included after the title of each task.

DISCUSSION

1. Isolation and Identification of Waterborne Pollutants Associated with the Power Industry--L. H. Howe, L. E. Scroggie, C. W. Holley

The reports will summarize results of laboratory studies to improve analytical procedures and provide acceptable alternate analytical methods for several pollutants in water samples from energy-critical areas in the Ohio and Tennessee River Valleys.

Specific tasks for which improved methods are being developed are: Acrolein by voltammetry at positive potentials; cadmium, lead, copper, zinc, simultaneously by voltammetry; compare digestion techniques for suspended and dissolved metals by atomic absorption; compare total arsenic by voltammetry, atomic absorption, and colorimetry; sulfate by high speed colorimetry.

Progress: Work was completed on acrolein in July 1975. A differential pulse polarographic method was developed for the determination of acrolein in natural and condenser cooling water. It is based on electrochemical reduction of acrolein at negative potentials at the dropping mercury electrode. The sample solution is buffered at pH 7.2 with a phosphate buffer solution, and ethylenediaminetetraacetic acid (EDTA) is added (0.09%) to prevent interference from zinc. The height of the polarographic peak at about -1.2 V vs. the saturated calomel electrode (S.C.E.) is measured and referred to a standard curve. The recovery of acrolein was unaffected by pH in the 6.8-7.6 range and by zinc at 2.0 mg/l. The range of the method is from 0.05 to at least 0.5 mg/l of acrolein. Replicate analyses of standard solutions containing 0.1 and 0.3 mg/l of acrolein gave relative standard deviations of 7.2 and 4.1% and relative errors of 2.8 and 3.3%, respectively.

Acrolein can also be determined by differential pulse voltammetry at the glassy carbon electrode. The acrolein is measured indirectly by forming the acrolein-sulfite complex and oxidatively measuring unreacted sulfite at positive potentials in a phosphate buffer solution at pH 7.2. This procedure does not require lengthy deaeration to remove oxygen, but its sensitivity (10 mg/l) makes it less attractive than the polarographic method.

Sulfite was tested as a preservative for acrolein samples. Acrolein could not be quantitatively recovered from solutions containing excess sulfite. On the basis of this work, sulfite is not recommended as a preservative.

The Laboratory Branch successfully employed a gaseous hydride method for arsenic by atomic absorption. We also have active methods for arsenic by voltammetry and colorimetry. Comparative experimental work is scheduled for completion by the end of February 1976.

An electrolyte purification apparatus was purchased to purify ammonium citrate buffer for determining cadmium, lead, copper, and zinc by anodic stripping voltammetry.

A literature review is being conducted on all tasks except acrolein.

Status: A galley proof of the draft milestone report for acrolein was submitted to EPA on December 1, 1975.

The draft milestone report for arsenic will be submitted to EPA by September 30, 1976.

2. Development and Evaluation of an Integrated Approach to the Optimization of Nuclear Power Plant Radiological Surveillance Programs--L. G. Kanipe, B. B. Hobbs, R. L. Doty, E. A. Belvin, J. A. Oppold

This study will identify and develop an optimum radiological surveillance program for nuclear power plants, providing results which will facilitate the efficient, reliable, and economical design of monitoring systems. In the first segment of the study, the objective will be optimization of the environmental radiological monitoring program. The second, concurrent segment of the study will be oriented toward the development of model quality assurance procedures for radiological surveillance programs.

Operators of nuclear power plants are required to conduct radiological surveillance programs to make certain any radiation exposures to plant employees and the general public are within safe limits. As part of these programs, numerous analyses are made at one or more laboratories for radioactive materials within the plant, at potential effluent release points, and in the environment. It is imperative that the accuracy and precision of the analytical data be assured. It is also necessary that in-plant and environmental data be comparable in order to develop and test models used for calculating potential movements of radionuclides from plant to environment. It is highly desirable that data generated throughout the nuclear power industry be comparable in order to assess regional and national effects of energy production by nuclear power. Research needs were identified within the nuclear technology regarding interlab quality control for radioanalytical laboratories and radiation monitoring guidelines. High priority was given to the collection of information and the development of programs pertinent to those needs.

TVA proposed a comprehensive program leading to the development of guideline information for the nuclear power industry. This program, using TVA's radioanalytical laboratories, included development of uniform quality assurance procedures through interlaboratory studies, development of methodologies, and evaluation and calibration of equipment. Procedures will be evaluated for reliability and comparability of data generated by different laboratories and their practicability for routine use in an operating surveillance program.

Because of its experience with nuclear power plant design and operations, TVA will develop uniform procedures for radiological surveillance. Participating laboratories will be operated by TVA which would reduce communication problems that might exist in an arrangement of plant operator and outside contractor. Further, assimilation of the proposed program into TVA's existing radiological surveillance operations could be accomplished at minimal cost compared to establishment of a separate surveillance program. Therefore, in response to the proposal, TVA was funded in fiscal year 1975 to initiate studies related to radiation monitoring guidelines and quality control.

Progress: All equipment for the project has been ordered. A pulse height analysis system (Nuclear Data ND-100) has been received and is undergoing performance-testing and calibration.

The exact needs of each participating laboratory are being determined in order to tailor the standards, methods, and interlaboratory studies to specific requirements in the development of the analytical quality control program.

The computer program "ALPHA-M" (E.O. Schonfeld) is being studied in detail to evaluate its application in gamma spectroscopy at environmental activity levels. A standard version of the program has been prepared and presently is being tested. Limits of detection (MDA) for single nuclide and multiple nuclide cases are being determined. Further studies of optimum library size and background subtraction options are being conducted.

An analytical quality control (AQC) manual for radioanalytical laboratories is being reviewed and revised prior to submission to EPA.

Status: Upon delivery, all counting equipment will be performance-tested and readied for operation. Upon completion of review, the AQC manual will be submitted to appropriate EPA staff. Work will continue on the establishment of criteria to evaluate monitoring data.

Project activities are proceeding on projected schedules. Some delays in administrative arrangements and in transfer of funds will require the revision of milestone completion dates. However, all of the specified tasks are expected to be completed within the projected duration of the project.

3. Remote Sensing of SO_2 Effects on Vegetation--A. L. Bates, H. C. Jones, W. R. Nicholas

The principal visible symptom of SO_2 injury to vegetation is discoloration of foliage. Delineation of these effects and documentation of their prevalence and severity is necessary for estimating air quality impacts in the vicinities of point or area sources. However, ground survey methods are costly and time-consuming for the following reasons:

1. The sizes of areas requiring inspection are relatively large (several hundred square miles).
2. Affected areas, fields, stands, etc., can be missed because of inaccessibility.
3. Rapid recovery of affected vegetation may mask effects.
4. Costs for obtaining statistically sound data on the degree and extent of effects can be prohibitive.

Remote sensing from aerial platforms could provide routine surveillance of large areas with permanent, quantitative documentation of the extent and severity of effects that could be compared with future data to determine trends. Furthermore, more subtle effects resulting from chronic exposure to pollutants might be detected more readily because site specific factors that mask pollutant effects would be averaged over large areas. The objective of this task is the testing and refinement of remote sensing techniques for detecting air pollution effects on terrestrial vegetation, primarily those caused by emissions from coal-fired power plants. Depending on current issues and funds, this may be expanded to include thermal effects from power plants in general. Initial studies involve comparison of ground effects on vegetation with color, color infrared, and multi-spectral imagery obtained by conventional aircraft. If these methods prove satisfactory, then the feasibility of satellite imagery for effects surveillance will be evaluated.

Progress: Aerial overflights of SO_2-affected agronomic crops, mainly soybeans and tobacco, were conducted in July 1975 following ground-level SO_2-exposures associated with the Shawnee and Joppa Steam Plants near Paducah, Kentucky. Color infrared, black and white infrared, aerial Ektachrome, and multispectral scanning imagery at different scales was obtained by NASA and TVA aircraft over the affected area and over appropriate control fields. No EPA/TVA pass-through funds were provided to NASA for this work. Concomitant ground-truth data were obtained on the physiological condition of the crop species and on edaphic characteristics. Soil and plant samples were collected for chemical analyses of soybean and plant crops, but have not yet been analyzed. Although a large portion of the imagery has been processed, interpretation of the imagery will not be completed until NASA has completed the upgrading of their computer facilities.

Status: Plans for 1976 are to repeat the studies for effects on soybeans and to initiate studies on the feasibility of remote sensing for detecting SO_2 effects on forest species. The study will be redirected, insofar as possible, to provide information on the Ohio Valley region between Paducah, Kentucky, and Cincinnati, Ohio, as a part of a special EPA integrated study.

THE ROLE OF STANDARD REFERENCE MATERIALS IN ENVIRONMENTAL MEASUREMENTS

J. R. McNesby
National Bureau of Standards
Washington, D. C.

The provisions of the Clean Air Act Amendments of 1970 and the Federal Water Pollution Control Act of 1972 include requirements to limit the emissions of pollutants from various points of dicharge such as automobile tailpipes and waste-water effluents. It is fairly obvious that such measures are required if we are to maintain our air and water in a sufficiently clean state for protection of the public health and welfare. What is not obvious is the exact extent to which it is necessary to limit the discharges in order to reach sufficient purity. As long as costs rise exponentially with degree of purification, we may expect public pressure to control only enough for adequate protection and no more. This economic fact underlines the critical necessity for the development of a valid environmental measurement system. There are two elements that are fundamental to such a system. First, we must establish as accurately as possible dose-response relationships so that ambient air and water quality standards can be set properly. Secondly, we must establish the relationship between pollutant concentrations at the point of discharge and at the point of human contact. Basic to this measurement system are the requirements that (1) health effects can be measured with requisite accuracy. (2) An accurate model is available. (3) The pollutant measurements at ambient and source concentrations are internally consistent. The part of the measurement system with which we at the National Bureau of Standards have been primarily concerned is the third of these. In the discussion that follows, it is presumed that the other two requirements are met.

The dissipation of a discharged pollutant depends upon a variety of parameters--wind, temperature, chemistry, sunlight, surface morphology, rain, biological conversion, etc. Modeling of such a complex system is relatively undeveloped. Recourse is taken to the so-called rollback or proportional model which is an admittedly oversimplified empirical model. This model, however, is acceptable to the EPA for state implementation of air quality regulations.[1] The proportional model is applied here to air pollution control. However, the conclusions regarding accurate measurement will be equally valid for water pollution.

The proportional model is defined by the assumption that the ambient pollutant concentration, C, is proportional to the total emission rate, R_T, which is the sum of the natural background emission rate, R_B, the auto exhaust emission rate, R_A, and the rate of emission from stationary sources, R_S.

$$R_T = R_B + R_A + R_S$$

$$C = kR_T = k(R_B + R_A + R_S)$$

Implied is the assumption that the contributions of the various sources to C are additive and are each themselves identically proportional to the respective emission rates.

$$C = C_B + C_A + C_S = kR_B + kR_A + kR_S$$

The achievement of an air quality standard, C^o, requires a fractional reduction, F, in all source emissions.

$$F = \frac{R_T - R_T{}^o}{R_T - R_B} = \frac{C - C^o}{C - C_B}$$

The term $R_T{}^o$ is the total emission rate at which the standard, C^o, is just met. The fractional reduction in source emissions, therefore, exceeds the fractional reduction in ambient pollutant concentration $(C-C^o)/C$ because of the dependence of F upon C_B, the natural background concentration. From these considerations[2], it may be concluded that the fractional reduction in the total stationary source emission rate is

$$F_S = \frac{R_S - R_S{}^o}{R_S} = \frac{R_A}{R_S}\,\frac{(C - C^o)}{C} - \frac{(R_A - R_A{}^o)}{R_S}$$

$$+ \frac{C - C^o}{C} + \frac{R_B}{R_S}\,\frac{(C - C^o)}{C}$$

The measurement of the ratio $(C-C^o)/C$ requires only precision and not accuracy since any bias in the measurement of C will cancel the same bias in the measurement of C^o (assuming linear response over the concentration range). However, R_A/R_S and R_B/R_S can only be obtained by independent measurement of R_A, R_S, and R_B each of which is done by a different method because of the greatly different circumstances of the measurements. There is no reason to expect that a bias in the measurement of R_A will be the same as in the measurement of R_S and R_B. Therefore, the measurement of each of these parameters must be done without bias (accurately). The rate R_B is determined by measuring C_B and k since $R_B = (1/k)C_B$. The quantities R_A and R_S are determined by measuring the concentrations in auto exhaust emissions, C_A, and in stack effluents, C_S, along with the respective rates of flow. It follows that C_A, C_S, and C_B must be accurately measureable if implementation of the air quality regulations are to be successful and economically acceptable.

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[1] Federal Register 36, No. 158, p. 15490, August 14, 1971.

[2] See J. R. McNesby, Berichte der Bunsen-Gesellschaft 78, 159 (1974) for a detailed mathematical treatment.

It is for these reasons that the National Bureau of Standards has undertaken to develop Standard Reference Materials whose purpose is to help eliminate bias from the measurement of C_A, C_S, and C_B. Accurate measurement of C_A is facilitated by NBS Standard Reference Materials of propane in air, carbon monoxide in nitrogen and nitric oxide in nitrogen. Accuracy of measurement of C_S is provided by NBS Standard Reference Materials CO in nitrogen and NO in nitrogen. There remains to be developed the SO_2 in nitrogen Standard Reference Material which should be completed by the end of 1976. This and other Standard Reference Materials are being developed under an agreement with EPA's Office of Energy, Minerals and Industry. The development of a Standard Reference Material of nitrogen dioxide in air is envisioned by June 1977 under the same agreement.

In the development of Standard Reference Materials for elimination of bias from the measurement of C_A and C_S, primary standard gas mixtures are prepared gravimetrically or volumetrically and are analyzed by other absolute techniques. Their stability is carefully studied both in the short and long term by NBS scientists. Next, a large supply of commercial gas cylinders containing nominal pollutant concentrations is purchased and concentrations are established and certified by comparison with the primary standards.

Standard Reference Materials applicable to accurate measurement of C_B and to ambient pollutant concentrations generally include the sulfur dioxide permeation tube and the nitrogen dioxide permeation tube. Under development is the carbon monoxide in air Standard Reference Material which is expected to be issued in December 1976.

It should be understood that all SRMs are not intended to function directly as calibrating materials for measuring instruments. This is due to the fact that interfering substances may be present in real samples which might produce an illusory signal on a measuring instrument. Further, if the response of an instrument is not linear, a one point calibration can be misleading. Under these circumstances, the purpose of an SRM is to provide the analyst with a material of known composition with which he can test his ability to perform accurate analysis.

Although the rationale describing the National Bureau of Standards' program in environmental measurement has been presented here in terms of air pollution, it is apparent that Standard Reference Materials are needed in water pollution for quite similar reasons. The National Bureau of Standards water pollution program is very young and has just issued its first Standard Reference Material of mercury in water at the ppm and ppb levels. Standard Reference Materials needs associated with new or increased energy usage will form the focus of our efforts over the next few years. We must anticipate the measurement and Standard Reference Materials needs that are likely to arise as new energy sources develop. To this end, NBS is conducting a series of workshops designed to reveal probable pollutants associated with the various emerging energy technologies. Four such workshops have already been held--Offshore Oil Drilling, Oil Shale Processing, Coal Gasification and Liquefaction and Desulfurization. Other workshops to be conducted by June 1976 include those on power plant operation, uranium mining, mine drainage and geothermal energy utilization.

Table I lists a number of materials currently being evaluated for issuance as NBS Standard Reference Materials along with target dates for completion of the feasibility studies.

Table I
Projected Energy Related SRMs

	Target Date
St. Louis Particulate	6/79
Raw Oil Shale	6/77
Spent Oil Shale	1/79
Toxic Metals in Water	6/76; 6/77
Organics in Water	6/78; 6/80
Organics in Sediment/Biota	6/79; 6/80
^{210}Po	1/76
^{226}Ra in Soil; Mixed gamma emitter solution, ^{239}Pu	1/77
Mixed gamma emitter soil	1/78
^{230}Th, ^{238}Pu, ^{241}Pu	1/78
^{241}Am, ^{242}Am, ^{235}U, ^{238}U	1/79
^{210}Pb, ^{232}Th, ^{243}Cm, ^{244}Cm	1/80

Other Standard Reference Materials relevant to the energy program which are already available from the National Bureau of Standards are Sulfur in Residual Fuel Oil, Lead in Reference Fuel, Sulfur in Coal, Trace Metals in Coal, Fuel Oil and Coal Fly Ash. A detailed listing of available NBS environmental SRMs may be found in NBS Special Publication 260, Catalog of NBS Standard Reference Materials, page 33.

EPA/NASA COOPERATION TO DEVELOP REMOTE SENSING AND IN SITU SENSORS AND TECHNIQUES FOR POLLUTION MONITORING

James R. Morrison
John Mugler and E. L. Tilton, III
National Aeronautic & Space Administration

INTRODUCTION

On May 2, 1975, the EPA and NASA concluded an Energy Memorandum of Understanding under which two projects are going forward at present. These relate to developing remote and in situ sensors and techniques to the measurement and characterization of power plant and other source effluents, and to obtaining baseline data and thereafter to monitor the rehabilitation of surface mining areas over a wide part of the Western United States. These two projects are discussed in some detail below.

REMOTE AND IN SITU INSTRUMENT DEVELOPMENT

As a result of the Clean Air Act, many large power plants have been required to burn low sulfur fuels. These fuels are becoming increasingly expensive and more difficult to obtain and consideration is being given to reverting to fuels with higher sulfur content if the environmental impact is acceptable. Thus, it is important to better characterize the effects of fuel quality (sulfur and ash content) on the local environment. This characterization must include a better understanding of effluent composition, dispersion processes, chemical reactions, and the influence of local meteorology and topography to guide decisions regarding fuel grade acceptability and plant siting, and thus minimize the impact of environmental regulations on our national resources. To achieve this understanding, improved remote and in situ measurement techniques are needed for proper study of stack effluent composition and dispersion processes. In addition, techniques are needed to measure emissions from other types of stationary and mobile sources. The objective of this project is to develop and apply advanced electro-optical techniques to the measurement and characterization of power plant and other source effluents.

DESCRIPTION OF WORK

To meet the project objectives, five tasks have been identified where additional funding would both complement the NASA research programs and meet specific needs of EPA. A description of each task is given below.

Task 1 - Raman Lidar

The objective of this task is to evaluate Raman lidar for remote measurement of the concentration of SO_2 at a powerplant stack exit. Raman optical radar systems have been developed at NASA and successfully applied in the measurement of water vapor and density profiles in the Earth's atmosphere (ref. 1). More recently, field tests have been conducted wherein the Raman technique was used to detect SO_2 in powerplant stack plumes (ref. 2); however, quantitative measurements of SO_2 require additional modifications and calibration of the lidar system. The necessary system modifications and calibrations have been done under this task. The modifications include reassembly of the lidar system used in reference 2 using a more compact telescope, improvements to the detection and data acquisition systems, and reformulation of data analysis programs (ref. 3). All modifications have been completed and a photograph of the modified system is shown in figure 1. Also, a calibration facility was constructed to calibrate the Raman lidar system for SO_2 and other gases. A schematic and photograph of this facility are shown in figures 2 and 3, respectively. The 2-meter diameter, 20-meter long calibration tank is charged with the calibration gas which is mixed with air in the tank to a known concentration. Raman lidar measurements are then made through a known volume and concentration of calibration gas. Calibration of the lidar system for SO_2 has been completed and the results reported in reference 3. These results show that, at a range of 300 meters and night background light levels, the Raman lidar system can measure SO_2 concentrations of 1,000 ppm to within 10% with a 30-minute measurement time.

Task 2 - Plume Dispersion Studies

The objective of this task is to apply aerosol scattering lidar techniques to the study of plume dispersion under various atmospheric conditions. NASA has developed lidar techniques for atmospheric measurements and for dispersion studies of plumes from rocket launches (ref. 4). EPA has developed plume dispersion analytical models to be used in studies relative to siting fossil fuel powerplants and lidar techniques can assist in the experimental validation of these models. Under this task, a NASA lidar system suitable for plume dispersion measurements will be assembled on a mobile platform. (See fig. 4) With this system, the laser backscatter from particles in the plume will be recorded and displayed to show three-dimensional profiles of the return signal. By averaging the returns over various time scales, the instantaneous and Gaussian aerosol profiles of the plume can be determined as a function of downwind range from the stack. After system checkout and calibration, the system will be used in a joint EPA/NASA field test to study powerplant plume dispersion under various atmospheric conditions and experimental results will be compared to model predictions. This task was originally scheduled for completion in October 1976; however, it appears that budget constraints will delay completion until late 1977.

Task 3 - IR DIAL

The objective of this task is to develop and apply the tunable infrared (IR) differential absorption lidar (DIAL) technique to the remote measurement of molecular plume effluents. A large number of molecules have absorption lines in the infrared portion of the spectrum. Also, the differential absorption technique, in which a sequential measurement is made first on an absorption line and then at a nearby wavelength off the absorption line (see fig. 5), can provide range-resolved data for particular gases. Thus, the IR DIAL technique has the potential for providing range-resolved concentrations for a wide variety of pollutant species. The tunable IR laser system will be calibrated using the calibration system described in task 1 and evaluated in joint EPA/NASA field tests at powerplant plumes selected by EPA. This is a four year developmental task with an initial evaluation and decision point occurring in May 1977.

Task 4 - Laser Heterodyne Detector

The objective of this task is to evaluate the use of the laser heterodyne detector technique as a means to increase the sensitivity of long path continuous wave absorption measurements using diffuse reflectors. Optical heterodyne techniques have been developed by NASA and successfully applied in solar radiometry and laser communications (refs. 5 and 6). More recently, optical heterodyne techniques have been studied by NASA for atmospheric pollution monitoring from aircraft and satellites in both active and passive modes. These studies show that the use of laser heterodyne detection offers advantages of high spectral resolution, high sensitivity, reduced interference from other pollutants or atmospheric constituents and vertical resolution of pollutant species (ref. 7). EPA has developed long path (approx. 600 meters) laser pollution monitoring systems which utilize mirrored reflectors and direct detection of the reflected signal. These systems could have wider application if diffuse reflectors such as mountains or buildings could be used in place of retroreflectors. However, when diffuse reflectors are used in existing systems, the weaker return signal coupled with the relatively low sensitivity of the detector degrades system performance to unacceptable levels. The use of a laser heterodyne detector in the long path laser monitoring system with diffuse reflectors shows promise of improving performance to levels equal to or better than for a system with mirrored retroreflectors. The purpose of this task is to evaluate the use of a laser heterodyne detector in systems of this type. The evaluation will consist of theoretical studies and laboratory and/or field tests with a NASA-developed laser heterodyne detector such as that shown in figure 6. This task is scheduled for completion in September 1976.

Task 5 - HCl Monitor

The objective of this task is to develop and deliver to EPA an improved in situ HCl chemiluminescent monitor evaluated at concentrations as low as 5 ppb HCl in ambient and polluted air. In support of its launch vehicle monitoring program, NASA has developed a chemiluminescent HCl monitor which can detect HCl concentrations from 50 ppb to 100 ppm. A photograph of this monitor in the field is shown in figure 7 and the instrument is described in reference 8. In October 1974, at EPA's request, NASA used this instrument in the Gulf of Mexico to monitor HCl concentrations downwind of an incinerator ship burning chlorinated hydrocarbon waste (ref. 9). Based on the performance of the instrument in measuring HCl concentrations in a combustion plume, EPA felt that, with some refinements, the instrument could provide a much needed technique for measuring ambient HCl levels (~5 ppb). The necessary refinements are being conducted under this task, which is scheduled to be completed in December 1976. At that time, an improved instrument will be delivered to EPA along with a technical report containing a description of instrument characteristics and an evaluation of the instrument performance at HCl concentrations as low as 5 ppb.

WESTERN ENERGY RELATED OVERHEAD MONITORING

INTRODUCTION

Our most abundant domestic fossil fuel is coal, and much of it occurs at depths where it can be mined by surface methods. Surface mining destroys existing natural communities completely and dramatically. Indeed, restoration of a landscape disturbed by surface mining in the sense of recreating the former conditions is not possible. Nevertheless, rising energy consumption, coupled with increasing difficulty in securing adequate supplies of natural gas and low sulphur crude[10] oil, is focusing attention on coal.

The controversy over surface mining has been centered mainly in the eastern United States, but now it is shifting to the American West. Unfortunately, the methods of rehabilitating mined areas in Appalachia, Europe, and other humid environments are not directly transferable to the arid and semi-arid West. Approximately 57 of our remaining coal reserves lie in the West, about one-quarter of which can be mined by surface methods.

The coal lands of the Western United States are quite different from others in the nation. They occur primarily in sparsely populated, mostly arid environments. Annual mean precipitation is low, ranging from four inches (100 mm) or less in some of the hot deserts to twenty or more (500 mm) in the higher mountains. When precipitation does occur, it may come as high intensity, short duration storms or as snowfall when plants are dormant. Extreme fluctuations in both annual and seasonal temperatures are to be expected.

The ecological process of vegetative succession, or the orderly process of community change, is extremely slow under such arid conditions. Where natural revegetation of a disturbed site may develop in five to twenty years on a high rainfall eastern U. S. site, it may take decades or longer for natural revegetation to develop in a desert. Not only should the condition of the site be evaluated thoroughtly in advance of any disturbance, but the consequences, benefits and costs of the prospective action should also be evaluated as they relate to both the potential for rehabilitation and the broader environmental and societal impacts.

The extent to which any disturbed landscape can be rehabilitated depends on many conditions--physical, ecological, geological, social, economic, and technological--and on the value people place on such conditions. Discussion of the problems of rebuilding disturbed land is further confused by vague terminology used to describe the concept of landscape reconstruction. Therefore, for the purposes of this document, we define our understanding of "rehabilitation" to mean that the land will be returned to a form and productivity in conformity with a prior land use plan including a stable ecological state that does not contribute substantially to environmental deterioration and is consistent with surrounding aesthetic values.

DESCRIPTION OF WORK

The Environmental Protection Agency (EPA) has requested NASA to develop techniques that would assist in the monitoring of energy extraction sites. A cooperative project, titled Western Energy Related Overhead Monitoring, was formally initiated in June 1975. The primary objective of the Project is to develop operational remote sensing techniques to rapidly monitor the success with which an energy-related extraction site has been, or is being, rehabilitated to a state suitable for its intended usage. This includes the determination of environmental baselines for the purpose of establishing rehabilitation criteria as well as environmental effects of mine mouth power plants. Because of the large amount of area and total number of sites to be monitored, an automated and quantitative analytical procedure is desired. Aircraft and satellite multispectral data collection and processing techniques appear to be the most promising approach for the near-term future. The hardware and software techniques for processing remote sensing data would be transferred from NASA to EPA throughout the five-year project. Both presently available hardware and software techniques and those developed during the course of the project would be transferred. This would allow the EPA to establish and man a fully operational energy-related overhead monitoring system and to make maximum utilization of their present aircraft capability while developing the processing facilities and personnel skills required to make further utilization of remote data acquired by satellite. Although maximum use would be made of present LANDSAT capability, Landsat resolution may not be adequate. However, it is anticipated that the 30-40 meter resolution to be provided by future satellites in the 1978 to 1980 time period may be adequate for monitoring energy activity. The capability for processing these data has been initiated using simulated 30 meter data acquired from aircraft.

Initially the program will concentrate on the development of aerial remote sensor techniques to monitor environmental factors of coal extraction and rehabilitation. It is anticipated that roughly 50% of the total effort will be to monitor these activities in the Northern Great Plains, Utah, Colorado, and Arizona. Sites of planned activity (e.g., within two years) and active sites will be included. Consideration of environmental impact on surface and near-surface water, soil condition and slopes, subsidence manifestation, vegetation density and speciation and other rehabilitation aspects will be included.

It is projected that approximately 30% of the program scope will be dedicated to monitoring environmental impact from mine mouth fossil fuel power plants. Both on-line and planned development sites will be monitored. In addition to activity in the Northern Great Plains, sites in Utah, Colorado, Four Corners, Arizona and Nevada will be considered. Specific parameters of environmental concern are impacts on surrounding vegetation vigor and density (e.g., from particulate and SO_2 emissions), and degradation of synoptic visibility.

It is projected also that approximately 15-20% of the work will relate to problems associated with oil shale extraction, conversion and rehabilitation. Monitoring the extent of environmental impact associated with accumulation of spent shale and potential related surface run-off into the drainage system will be considered. Fugitive dust from spent shale may be of concern depending on the effectiveness of revegetation efforts. Most of the initial coverage will be of undeveloped potential oil shale sites. Monitoring will continue as extraction and rehabilitation activities proceed.

A minor effort will be made to develop monitoring techniques applicable to the development of geothermal prospects.

The project will be conducted in three phases, as shown in Fig. 8. The initial data acquisition activity deals with technique development associated with on-line coal surface mining sites. Such sites were chosen because of mine activity being of most immediate concern to EPA and because of other ongoing complementary ground investigations. The fourteen coal surface mining sites selected by EPA on this basis are presented in Fig. 9.

Following the final definition of system parameters, a large scale demonstration will be conducted. Hardware for a low-cost data system has been specified, and low-cost system hardware is being procured and transferred to EPA along with the appropriate software. Throughout the project, NASA and EPA personnel will cooperate in all phases of data acquisition, processing, analysis and evaluation. All phases of the project will be documented.

EPA will be responsible for determining ing whether or not to initiate an EPA operational system at the end of Phase 2 of the project.

EPA is responsible also for providing and coordinating the ground measurements of site- or activity-specific terrain parameters which, when remotely measured, will provide the basis for determining quantitative environmental impact assessment. Examples of these key parameters of features include surface contours, vegetative density, vigor and types, subsidence features, synoptic visibility, etc.

The present status of the project is as follows. Aircraft data have been acquired during the 1975 green peak in July at altitudes of 1, 3, 6, 12 and 60 thousand feet on fourteen surface mine sites Airborne terrain profiler data was acquired at 1 and 3 thousand feet to measure surface slope and roughness while multispectral scanner data was acquired at 3 through 12 thousand feet. Photographic data was acquired at all altitudes. One strip mine site, Amax Coal Company in Campbell County, Wyoming was selected for initial data processing because it was representative of the other sites, data quality was good from all altitudes, and because extensive surface data was available at this site.

A preliminary classification of surface materials was prepared using the multispectral scanner data from 12 thousand feet and spectral pattern recognition processing techniques. The results showed large areas of unclassified materials indicating inadequate initial training of the pattern recognition programs and a greater separability of soils and natural vegetation at this 10 meter resolution than originally anticipated. Additional training samples were selected and the data reclassified. The classification has been greatly improved and the improved separability of two key parameters, natural vegetation and soils, is encouraging with respect to higher altitude monitoring. As the 12 thousand foot data is refined, processing has started on the 3 thousand foot data and the 12 thousand foot data has been degraded to 30 meter resolution to determine the effects of resolution on monitoring capability.

With regard to hardware, all processing equipment for the EPA low-cost data system has been ordered and is scheduled for delivery in February 1976. The system should be operational in late March 1976 allowing the commencement of data processing on all remaining data from July 1975.

In addition to the aircraft data, some cloud-free Landsat data have been located over the surface mine sites in the July 1975 time frame and will be processed to determine utility in monitoring sites at 80 meter resolution.

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Figure 1. - Photograph of Raman lidar system.

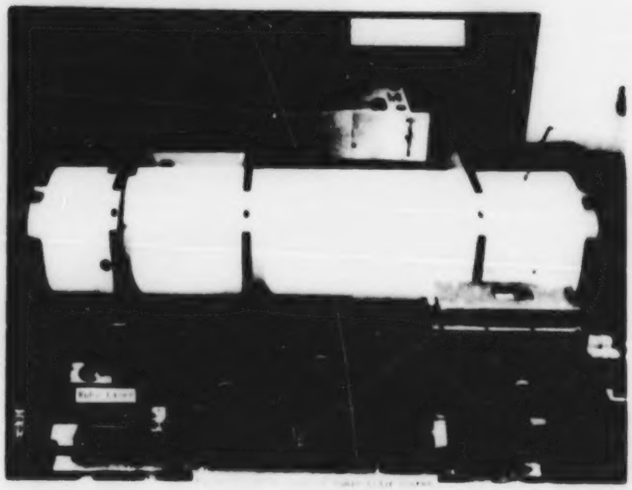


Figure 2. - Schematic of lidar calibration facility.

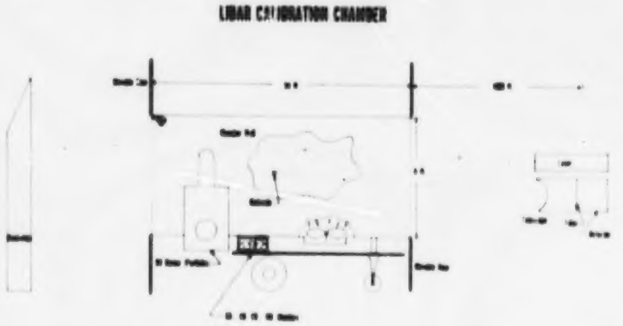

LIDAR CALIBRATION CHAMBER

Figure 3. - Photograph of lidar calibration facility.

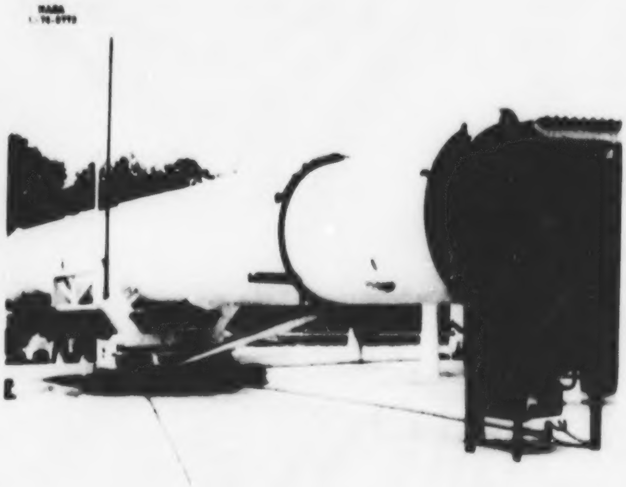


Figure 4. - Photograph of plume dispersion lidar system.

Figure 5. - Differential absorption lidar concept.

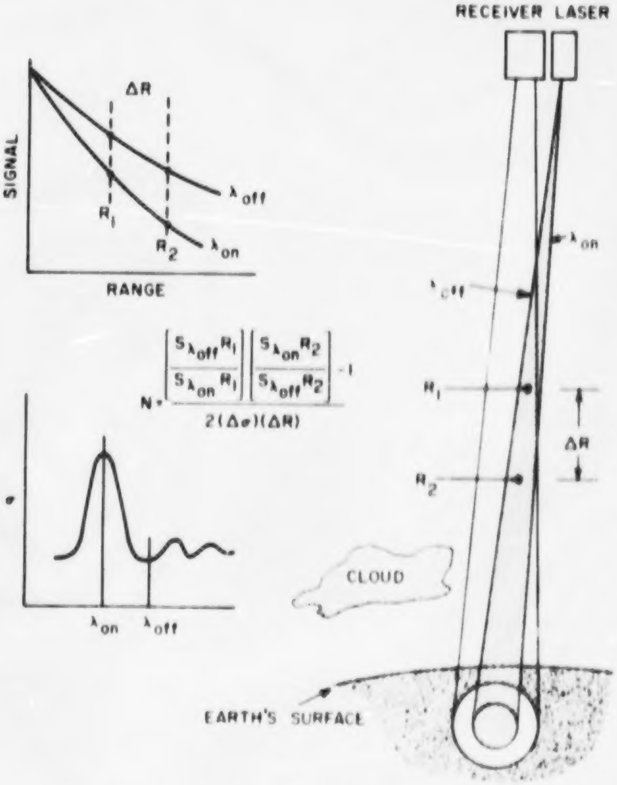

RECEIVER
LASER
ΔR
SIGNAL
λ_{off}
R_1
R_2
λ_{on}
RANGE
$N = \frac{\left[\frac{S_{\lambda_{off}}R_1}{S_{\lambda_{on}}R_1}\right]\left[\frac{S_{\lambda_{on}}R_2}{S_{\lambda_{off}}R_2}\right]^{-1}}{2(\Delta\sigma)(\Delta R)}$
σ
λ_{on}
λ_{off}
λ_{on}
λ_{off}
R_1
R_2
ΔR
CLOUD
EARTH'S SURFACE

Figure 6. - Photograph of laser heterodyne detector.

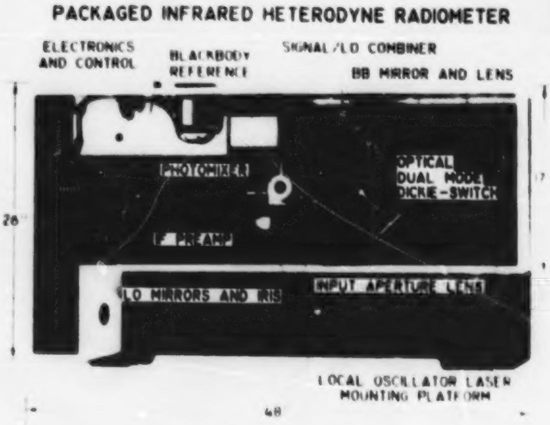

PACKAGED INFRARED HETERODYNE RADIOMETER
ELECTRONICS AND CONTROL
BLACKBODY REFERENCE
SIGNAL/LO COMBINER
BB MIRROR AND LENS
PHOTOMIXER
OPTICAL DUAL MODE DICKIE-SWITCH
IF PREAMP
LO MIRRORS AND IRIS
INPUT APERTURE LENS
LOCAL OSCILLATOR LASER MOUNTING PLATFORM
28
17
48

Figure 7. - Photograph of hydrogen chloride monitor in the field.

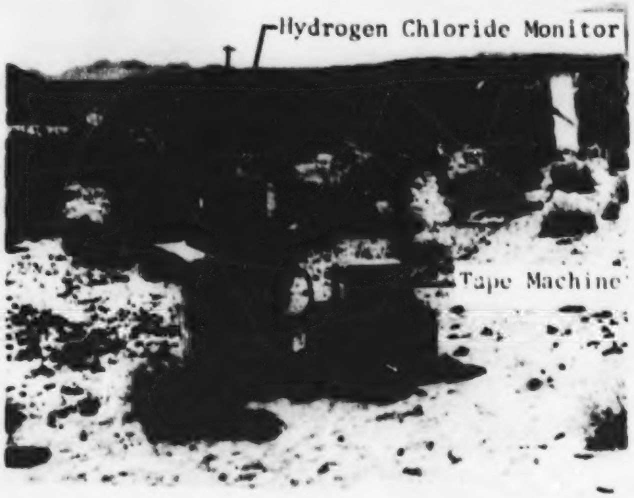

Hydrogen Chloride Monitor
Tape Machine

Figure 8

WESTERN ENERGY RELATED OVERHEAD MONITORING PROJECT

5 YEAR PROJECT TASK SUMMARY

PHASE 1
MONITORING TECHNIQUE DEVELOPMENT

July 75 - Dec 76

STRIP MINE RELATED

- inventory all selected sites
- Verify/evaluate existing techniques (LANDSAT, A/C data with ADP)
- Compare capability to low altitude A/C data
- Evaluate accuracy/cost
- Develop/document new techniques as required
- Define demonstration system and techniques (hardware/software)

POWER PLANT RELATED

- Evaluate capability to determine vegetation stress due to energy-related processing emissions

OIL SHALE RELATED

- Map oil shale site for pre-development baseline

GEOTHERMAL RELATED

(To be determined)

PHASE 2
MAJOR DEMONSTRATION

Jan 77 - july 78

ALL AREAS OF EMPHASIS

- Extend techniques and system to all sites
- Total inventory and periodic monitoring (progress/change)
- Major demonstration of monitoring capability over a large number of test sites
- Training of EPA personnel
- Transfer of known techniques, e.g. acreage measurement system, acreage change detection

PHASE 3
OPERATIONAL IMPLEMENTATION
and NEW TECHNIQUE TRANSFER
July 78 - july 80

ALL AREAS OF EMPHASIS

- Software/hardware modifications
- Continuation of training
- Consultation

Figure 9

Site #	EPA Site #	Mine	County/State	Comments
1	7E	Glen Harold	Oliver/ND	Potential winter synoptic visibility study
2	10E	Indian Head	Mercer/ND	Large homogeneous training areas
3	13E/M	Savage	Richland/MT	Good natural mix of training area types
4	15E/M	Big Sky	Rosebud/MT	Intensive ground truth activities being conducted
5	16E/M	Colstrip	Rosebud/MT	Intensive ground truth activities being conducted
6	19E/M	Sarpy Creek	Bigham/MT	Small site
7	21E/M	Decker Coal	Big Horn/MT	
8	25E	Wyodak	Campbell/WY	
9	26E	Amax	Campbell/WY	Good site for ERTS and EOS test
10	30E	Dave Johnston	Converse/WY	Year to year regeneration study being conducted
11	41B	Henry Mountain	Garfield/UT	
12	43B	Black Mesa	/AR	
13	44A/S	Navajo	San Juan/NM	
14	46A/S	McKinley	McKinley/NM	

WATER MEASUREMENT AND MONITORING IN ENERGY DEVELOPING AREAS

Frederick A. Kilpatrick
U.S. Geological Survey
Reston, Virginia

INTRODUCTION

The U.S. Geological Survey became officially involved in environmental monitoring in 1902 with the formation in the agency of the Division of Hydro-economics. This was 10 years before the formation of the Public Health Service. During this early life of the organization emphasis was placed on stream pollution studies; in fact, as early as 1911 a report on stream pollution by Kansas mine water was issued (U.S. Geol. Survey Water-Supply Paper 273).

Thus the Survey has been active in environmental monitoring for many years and assistance to numerous Federal, State, and local agencies is commonplace. The Survey has always been known as a research and basic-data-oriented organization based on a strong in-house capability. While this capability is often strained, the Survey has been able to maintain its objective, scientifically-oriented position as an unbiased agency in water monitoring. It is the intention to continue this neutrality in water monitoring as being in the best public interest.

WATER MONITORING PROGRAM

Long before the energy crisis, the U.S. Geological Survey operated a rather extensive water quality, quantity, and sediment monitoring network in the Rocky Mountains and Northern Great Plains States where there now is great interest in development of major fossil fuel resources. With the sudden emphasis on investigations in this region, the Survey, with assistance from the U.S. Environmental Protection Agency and other agencies, began promptly to increase the number of monitoring stations and to upgrade existing stations. Although expansion of the program emphasizes regional investigations, site-specific studies of mine-related problems are also being expanded elsewhere in the belief that much can be learned from past experience, and that coal production in existing mining areas will also expand to meet anticipated needs. Thus the scope of the monitoring program that will be described is nationwide, but is confined to that part financed by the EPA.

WATER MONITORING INSTRUMENTATION DEVELOPMENT PROGRAM

The development of fossil fuel resources in the arid and semi-arid lands of the West has placed increased strain on available measuring techniques and equipment for monitoring water quality, quantity, and sediment. Indeed, there is probably no more difficult an area in which to accurately measure the various parameters involved in assessing the impacts of mining and related industries. Research to support the monitoring program is concerned with the development of instrumentation for sampling, measuring, and/or monitoring water pollutants and sediments associated with energy-related developments, especially petrochemicals, toxic substances and sediment, and sediment-laden flows.

PROGRAM DISCUSSION

1. Water Monitoring Instrumentation Development

Research in this program is aimed at improvement and/or development in essentially five areas of need in water measurement and monitoring. The objective of each along with progress to date are discussed below.

a. Development of Methods for Characterizing and Monitoring Levels of Chronic Toxicity

Standard methods for characterizing and monitoring toxic substances at sub-lethal concentrations in aquatic ecosystems have not yet been established. Field data (and data from experimental streams) on effects of continuing low concentrations of toxicants on composition and productivity of aquatic ecosystems, are largely lacking. The general objective of this investigation is to determine, through detailed studies of organisms, simplified models of ecosystems and natural sites, the extent to which trace contaminants (especially trace metals) in different aquatic environments are available for biological uptake, influence the production and structure of plant assemblages, affect the growth and production of animals, and thus determine the trophic relationships and composition of aquatic communities.

Critical reviews have been conducted of the published literature and an analysis made of experiences of other research workers with procedures for measuring effects on aquatic organisms and aquatic ecosystems of chronic exposures to trace contaminants. Responses to many inorganic and organic toxicants have been considered but emphasis has been placed on substances released to the environment as a consequence of fuel extraction and combustion.

Assessment of the relative availabilities of Ag, Cd, Co, and Zn from six different physicochemical forms of bound metal have been completed. It was shown that uptake of sediment-bound metals is less rapid than uptake of solute metals. The rates of uptake of the former may vary as much as three orders of magnitude among sediment types for a given metal. Combinations of certain chemical extractions appear to be useful in allowing prediction of relative biological availability from sediments. Attempts to verify these predictive techniques using field data are in progress.

b. Development of Instrumentation for High-Volume Analysis of Petrochemical and Associated Compounds

The objective of this study is to develop guidelines in choosing equipment, analytical methods, and data processing ware for automation to accomplish the high volume analysis of petrochemicals and associated compounds. Initial efforts have been directed at computer automation of gas chromotography equipment and gas chromotography-mass spectrography equipment.

c. Development of an In-Situ Suspended Solids Sensor

The objective of this research is to develop an in-situ instrumentation system capable of measuring the mass concentration of sediment in water. Following laboratory tests of one or more commercially available sensors, and the design of an automatic data logging system, a complete package of components will be tested in the laboratory and eventually in the field. Although the equipment survey is only partially complete, a Dynatrol density gage has been selected for laboratory tests. This is a flow-through device with an electrical output signal. Signal frequency is a function of fluid density that, in turn, is a function of sediment concentration. Tests have been performed on a variety of sediments that include glass beads, blasting sand, and soil samples. At low sediment concentrations, random errors become significant. For concentrations between 100 and 500 mg/litre, random errors are approximately ± 150 mg/litre. For concentrations exceeding 500 mg/litre, concentration can be determined within approximately ± 15% of the true value. The dynamic range exceeds two log cycles. Concentration as high as 130,000 mg/l have been tested with no significant departure from a linear response.

Alternate methods of data storage and transmission are being studied. Data may be stored or recorded at the site by using a cassette tape recorder or a strip chart recorder. Transmission by telephone or even a satellite are other possibilities.

d. Development of Bedload Samplers for Measuring Stream Sediment

Expansion of mining for accelerated energy development has the threat of increased erosion and delivery of sediment to existing stream channels. Much of the sediment will be transported as bedload. In order to assess effects of sedimentation on water quality and stream ecology, and to plan remedial measures, it is essential to quantify bedload transport by actual measurements. At the present time, no existing samplers are completely satisfactory for measuring bedload transport. The objective of this investigation is to develop an acceptable sampler(s) for measuring the discharge of bedload particles that range in size from about 2 to 64 millimetres.

The sampler testing and calibration program will be carried out at the University of Minnesota's St. Anthony Falls Hydraulic Laboratory in a flume 9 feet wide, 6 feet deep, and about 250 feet long with a discharge capacity of 300 cubic feet per second. With this flume, hydraulic variables can be adjusted to produce bedload transport rates of up to at least 3 pounds per second per foot of width across the full 9-foot width and with depths of at least 3 feet. Samplers to be tested initially are being constructed. One of the samplers of primary interest is the Helley-Smith sampler, which is a pressure-difference-type sampler that has been used recently by several investigators.

e. Development of Flumes and Weirs for Measuring Sediment-Laden Stream Flows

The measurement of sediment concentration alone does not adequately measure total sediment discharge; along with the measurement of sediment concentration must be the measurement of water discharge. Because of the unstable nature of natural channels and the flashiness of runoff events in the arid and semi-arid regions of the West, new and/or improved flow measurement devices and techniques are needed. The objective is to develop and field test flumes, weirs, and other types of control structures particularly suitable for measuring sediment and debris-laden flows.

To date two experimental weirs have been installed on the Belle Fourche River in Wyoming; two are planned for the Piceance Creek in Colorado; five are planned for various streams in the Uinta Basin of Utah; and two experimental pre-calibrated measuring flumes have been installed on a tributary of the North Fork of the Kentucky River, Kentucky. The suitability of these experimental devices will be determined in use.

2. Water Monitoring Program

The USGS-EPA program in water monitoring can be divided into programs covering the Northern Great Plains and Rocky Mountains States, the area of greatest immediate concern; and site-specific studies that are being conducted elsewhere in the Western and Eastern sections of the country in coal fields with long histories of operation. These monitoring programs are concerned with the measurement of a complete suite of parameters in both ground-water and surface-water regimes. The principal purpose in all areas of the monitoring program is to provide the baseline data coverage necessary to assess any changes that may occur as a result of energy industry development. The monitoring program will be discussed as pertinent to each region and regime.

a. Surface-Water Monitoring in the Northern Great Plains and Rocky Mountains States

The surface water monitoring program in the Rocky Mountains and Northern Great Plains States both supplements and complements on-going work of the Water Resources Division of the U.S. Geological Survey in these States. The water quality monitoring stations on the tributaries of the Colorado River draining the oil shale regions of Colorado have been increased in number and the suite of analyses being performed broadened. In the oil shale region of Utah the suite of parameters has been broadened and includes biological coverage.

The number of monitoring stations and the suite of parameters being acquired have been augmented in the coal regions of the Yampa, Yellowstone, and Tongue Rivers, the Upper Missouri River tributaries, and tributaries of the Green River draining eastern Utah and Wyoming.

Table 1 summarizes the location and frequency of sampling at 47 stream sites in the Northern Great Plains and Rocky Mountains States. This table also shows the types of analyses being performed starting in August 1975. No attempt will be made to discuss results at this early date.

b. Ground-Water Monitoring in the Northern Great Plains and Rocky Mountains States

The ground-water monitoring program in the oil shale regions focuses on the collection of geochemical data in the Piceance Creek Basin of Colorado and the Uinta Basin of Utah. Beside the use as a baseline against which any future impacts may be assessed, these data are also required to help calibrate models that can be used to predict the impact of oil shale extraction, waste disposal, and water storage reservoirs on the ground-water systems.

Ground-water studies in the coal regions of Colorado, Wyoming, Utah, Montana, and North Dakota are principally aimed at obtaining geohydrologic, geochemical, and physical data describing the ground-water systems in order to facilitate the prediction of potential mining impacts. As with the oil shale monitoring, the data will also provide a basis for assessing future impacts.

Table 2 summarizes the parameters being analyzed. The data collection period is too brief to warrant meaningful discussion of results at this time.

c. Surface-Water and Ground-Water Monitoring in the Western and Eastern United States

While emphasis has been placed on the effects of developing the energy resources of the Rocky Mountains and Northern Great Plains States, the environmental impacts of increased coal mining must be expected in most of the United States. In districts with long operational histories much can be learned by assessing the impacts on hydrologic systems. Moreover, there is a Federal obligation to acquire baseline data in on-going mining areas where new mining is imminent as a basis for rational decision-making at the National level.

The following seven EPA-supported projects are part of the comprehensive surface-water/ground-water monitoring and hydrologic assessment program taking place at actual and potential mining sites in the Western and Eastern areas of the country:

1. Black Mesa Area, Arizona -- Effect of Strip Mining on the Hydrology of Small Watersheds
2. The Centralia Mine, Washington -- [illegible] Strip Mining, Land Reclamation, and Water Quality Monitoring Practices
3. New River Basin, Tennessee -- Assessment of the Hydrologic Effects of Strip Mining
4. Wabash River in Indiana -- A Reconnaissance of the Effects of Strip Mining and Reclamation
5. Southeastern Ohio -- Characterization of Mine Drainage

6. Illinois -- Characterization of Mine Drainage

7. Alaska -- A Preplanning Study of the Hydrologic Effects of Development of Alaska's Coal Resources

The first four studies are site-specific, investigating the impacts of existing or impending localized mining.

The Black Mesa Study involves the hydrologic modeling of three small watersheds in northeastern Arizona prior to mining; to be followed by monitoring of conditions throughout the period of mining and rehabilitation.

The Centralia Mine Study is an assessment of an existing mining and reclamation project where practices appear to conform to most of the regulations proposed in the strip mine legislation now before Congress.

The New River Study focuses on the assessment of water quality throughout a basin where there is extensive strip mining and in the determination of downstream changes in sediment load and associated metals.

The study in the lower headwaters of the Wabash River in southwest Indiana is concerned with monitoring pre to post mining water quality changes in a hydrologic system adjacent to an area to be mined.

The studies in Ohio and Illinois are reconnaissance level evaluations of the occurrence and distribution of basic inorganic and organic constituents in surface and ground waters in the coal mining regions of the two States. These studies will relate water quality to basin characteristics and make the data available to those seeking a solution to water degradation in mined areas.

The Alaska study will evaluate the probable hydrologic effects and establish the kinds of hydrologic data needed to asses the environmental impact of coal mining operations in Alaska. It will outline the most likely areas for development of mining operations and anticipated hydrologic problems peculiar to those areas.

Time and space do not permit more elaboration on these studies as each is worthy of a report and will be reported on as progress warrants.

RESOURCE ALLOCATION

A breakdown of the funding by the EPA and the U.S. Geological Survey for ground-water and surface-water monitoring and the related instrumentation development projects in which the two agencies are cooperating is as follows:

($ x 10^6)

	FY 75		FY 76	
	USGS	EPA	USGS	EPA
Instrumentation Dev..	0.242	0.565	0.250	0.380
Monitoring: Rocky Mts. & N. Great Plains				
SW	0.197	0.199	0.240	0.175
GW	0.783	0.179	0.850	0.125
Monitoring: West & East United States				
SW & GW	0.127	0.295	0.150	0.309

It should be noted that U.S. Geological Survey funds listed are just for those programs discussed in this report and comprise only a small part of the Survey's total energy-related program.

CONCLUSIONS

The U.S. Geological Survey, with the financial assistance of the Environmental Protection Agency, has well underway comprehensive nationwide programs to monitor surface-water and ground-water regimes in new as well as long established coal fields and oil shale mining areas. While emphasis is placed on the rapidly developing Rocky Mountains and Northern Great Plains States, other studies in which EPA is cooperating are looking at the impacts being experienced in existing coal mining areas nationwide. In addition, a program of instrumentation development is focusing on upgrading capabilities in obtaining accurate data so that better assessments can be made.

These programs have been in progress only a relatively short time. Coal mining, reclamation, and the conversion and utilization of our fossil fuels in their many forms, as well as the ensuing impacts will be with us ad infinitum, so our efforts to monitor, assess, and live with this industry in an environmentally acceptable manner must be looked upon as a long-range effort.

Table 1

Surface-water monitoring sites, frequency and types of sampling in the coal and oil shale regions of the Northern Great Plains and Rocky Mountains States

M=Monthly Q=Quarterly

Stream site	Emission spectrographic pesticides, radioactivity	Field measurements (1)	Chemical (2)	Nutrients (3)	TOC, oil and grease (4)	Metals (5)	BOD (5-day)	Suspended sediment	Turbidity	Phytoplankton	Periphyton	Bacteriological (6)	Flow
	Frequency of observation												
COLORADO													
Yampa R. below diversion nr Hayden		M	M	M	Q	Q	M	M	M	M	Q		1/
Yampa R. downstr of Elkhead Cr.		M	M	M	Q	Q	M	M	M				1/
Yampa R. downstr from Yampa Project diversion and coal mine area		M	M	M	Q	Q	M	M	M	M	Q		1/
Williams Fork R. nr Hamilton		M	M	M	Q	Q	M	M	M	M	Q		1/
White R. below Meeker	Q	M	M	M	M	Q		M	M	Q	Q	M	1/
White R. above Rangely	Q	M	M	M	M	Q		M	M	Q	Q	M	1/
Parachute Cr. immediately downstr from East and West Fk confluence	Q	M	M	M	M	Q		M	M	Q	Q	M	1/
Logan Wash at mouth	Q	M	M	M	M	Q		M	M	Q	Q	M	1/
MONTANA													
Yellowstone R. at Myers		M	M	M	Q	Q	M	M	M	M	Q		1/
Yellowstone R. at Forsyth		M	M	M	Q	Q	M	M	M				1/
Tongue R. below Hanging Woman Cr		M	M	M	Q	Q	M	M	M	M	Q		1/
Yellowstone R. near Terry		M	M	M	Q	Q	M	M	M	M	Q		1/
Yellowstone R. at Laurel					Q	Q	M	M					1/
Yellowstone R. at Huntley					Q	Q	M	M					1/
Yellowstone R. near Miles City					Q	Q	M	M		M	Q		1/
Yellowstone R. near Sidney							M						1/
NORTH DAKOTA													
Missouri R. at Williston		M	M	M	M	Q	M	M	M	M	Q		1/
Missouri R. at Garrison		M		M	M	Q	M		M				1/
Spring Cr. at Zap		M	M	M	M	Q	M	M	M	M	Q		1/
Knife R. nr Hagen		M		M	M	Q	M		M				1/
Missouri R. at Bismarck			M		M	Q	M	M					1/
Missouri R. at Schmidt		M	M			Q	M	M					1/
UTAH													
Duchesne R. nr Randlett		M	M	M	M	Q		M	M	M	Q		1/
Price R. at Woodside		M	M	M	M	Q		M	M	M	Q		1/
Dirty Devil R. nr Hanksville		M	M	M	M	Q		M	M	M	Q		1/
White R. upstr confluence with Green R.	Q	M	M	M	M	Q		M	M	M	Q	M	1/
WYOMING													
Piney Cr. at Ucross		M	M	M	Q	Q			M			M	1/
South Fork Powder R. at Kaycee		M	1/	M	Q	Q			M			M	M
Cheyenne R. near State line		M	M	M	Q	Q			M			M	M
Little Powder R. at State line		M	M	M	Q	Q			M			M	1/
Little Missouri R. at New Haven		M	M	M	Q	Q			M			M	M

M=Monthly Q=Quarterly

Stream site	Emission spectrographic pesticides, radioactivity	Field measurements (1)	Chemical (2)	Nutrients (3)	TOC, oil and grease (4)	Metals (5)	BOD (5-day)	Suspended sediment	Turbidity	Phytoplankton	Periphyton	Bacteriological (6)	Flow
	Frequency of observation												
Bitter Cr. below Rock Springs		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		M			M	M
Hams Fork below Kemmerer		M	[illegible]	[illegible]	[illegible]		M		[illegible]			M	M
Big Sandy below Eden		[illegible]	[illegible]	M	[illegible]	M			[illegible]			M	[illegible]
Killpecker Cr. at mouth (Rock Springs)		M	M	[illegible]	[illegible]	[illegible]			[illegible]			M	M
Twin Cr. at Sage		M	M	[illegible]	[illegible]	[illegible]			[illegible]			M	M
Green R. near Labarge		[illegible]	[illegible]	M		[illegible]	[illegible]	[illegible]	M			[illegible]	[illegible]
Green R. below Fontenelle Reservoir		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		M			[illegible]	[illegible]
Green R. near Green River			[illegible]			[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]
Green R. below Green River		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]			[illegible]	[illegible]
Tongue R. at Monarch		M	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]				[illegible]
Powder R. at State line (Moorhead)		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	M	M	[illegible]	[illegible]		[illegible]
Tongue R. near Dayton		[illegible]		[illegible]		[illegible]	[illegible]	[illegible]	M	[illegible]	[illegible]		[illegible]
Goose R. below Sheridan		M		[illegible]		[illegible]	[illegible]	[illegible]	M				[illegible]
Tongue R. at State line		[illegible]		[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
Clear Cr. near Arvada		M		[illegible]			[illegible]	[illegible]	[illegible]				[illegible]
Belle Fourche R. at Devils Tower		[illegible]		[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]

(1) Field - water temperature, specific conductance, pH, [illegible] [illegible], dissolved oxygen, and alkalinity.

(2) Chemical - calcium, magnesium, sodium, potassium, silica, fluoride, iron, bicarbonate, carbonate, chloride, sulfate, dissolved [illegible] [illegible], [illegible] and boron.

(3) Nutrients - total nitrate+nitrite, total orthophosphate, total Kjeldahl nitrogen, and total ammonia.

(4) Total Organic Carbon - total organic carbon and dissolved organic carbon.

(5) Metals - total and dissolved metals (As, Al, [illegible], Cd, Cr, Cu, Fe, Pb, [illegible], Mn, Hg, Mo, Ni, Se, V, and Zn).

(6) Bacteriological - total and fecal coliform.

1/ Furnished under other programs.

2/ Specific conductance, pH, temperature, and dissolved oxygen furnished under other programs.

Table 2 - Parameters to be analyzed on selected ground-water samples in the coal and oil shale regions of the Rocky Mountains and Northern Great Plains

1. Dissolved Solids
2. Alkalinity
3. Dissolved Silica
4. Dissolved Aluminum
5. Dissolved Iron
6. Dissolved Manganese
7. Dissolved Calcium
8. Dissolved Magnesium
9. Dissolved Sodium
10. Dissolved Potassium
11. Bicarbonate
12. Carbonate
13. Dissolved Sulfate
14. Dissolved Chloride
15. Dissolved Fluoride
16. Dissolved Bromide
17. Dissolved Nitrite and Nitrate
18. Dissolved Ortho-Phosphorus
19. Dissolved Barium
20. Dissolved Boron
21. Dissolved Lead
22. Dissolved Lithium
23. Dissolved Molybdenum
24. Dissolved Selenium
25. Total Strontium
26. pH
27. Carbon Dioxide
28. Dissolved Arsenic
29. Dissolved Copper
30. Dissolved Cadmium
31. Dissolved Mercury
32. Dissolved Zinc
33. Dissolved Oxygen
34. Specific Conductance
35. Suspended Solids or Sediment
36. Beryllium
37. Chronium
38. Nickel
39. Vandium
40. Radioactivity (α & γ)
41. Turbidity
42. Dissolved Organic Carbon
43. Radon
44. Coliform, Fecal and Total
45. Micro-and Macro Invertebrate Analysis
46. Phytoplankton
47. Periphyton

DISCUSSIONS TO MEASUREMENT AND MONITORING SESSION

Question: Does NOAA plan to implement a measuring or monitoring program to advance the State-of-the-Art with respect to the fate of radionuclides in offshore nuclear power plant ecosystems?

Panel Response: Fate of radionuclides generally is the jurisdiction of ERDA. However, NOAA is developing an extensive program to monitor pollutants in the marine environment. Current programs include building instrumentation for a more efficient monitoring system for underway vessels or from single point source location such as oil rigs. These facilities when constructed and operational could be utilized to monitor offshore nuclear power plants.

Question: What are the USGS's plans for developing monitoring and instrumentation equipment necessary for these systems to determine chronic effects in groundwater systems from pollutants released to or impact with the ground?

Panel Response: It is actually a system package of available instrumentational methods that is being synthesized. As far as is known, there is no actual new instrumentational hardware being produced to provide this physiological approach.

Question: What techniques are used to monitor either thermal or chemical pollutants in groundwater?

Panel Response: As stated previously, groundwater monitoring programs utilize existing or modified instrumentation or techniques. First, the pollutant is characterized with time and exposure to the elements. Its transport to the groundwater is then determined. Then the method for monitoring is evaluated and tested.

Question: Are the current methods that are under development for aerosol characterization adequate for interpretation for health effect studies?

Panel Response: The National Bureau of Standards and the University of Minnesota have a cooperative project to develop a real time sulfur particulate analyzer which is fundamentally based on the iron mobility analyzer and which uses photometry as a detection element. Considerable amount of work is also going on at RTP to look at particle sizes and distributions and species in various urban atmospheres. Attempts to use the electron microscope and optical microscopy to identify particles is also being conducted. The use of EPA's lidar system was amplified. It is used only to determine the height of the inversion layer and where the particulates are located; it has no quantitative capability, however, it does provide qualitative information very rapidly. Other responses indicated that EPA is also studying the use of laser photosensing techniques for various crops and pollutants. In addition to the above panel responses, an EPA representative from the floor indicated that EPA has an extensive R&D program for measurement which is not funded by energy-related sources such as collecting aerosols, analyzing for sulfates and sulfuric acid, development of fundamentals of upwind pointing lidar, use of spectrometers, and active type ozone and CO laser systems.

Question: Wished the TVA panel member to amplify on progress to develop capabilities for sensing effects of SO_2 on vegetation.

Response: TVA is just getting into this particular program and developing its capabilities. During the past growing season in conjunction with NASA and EPA, TVA used remote sensing imagery to attempt to evaluate cumulative effects of emissions from one of the TVA's plants. The data is still being evaluated. Other crop species are to be evaluated in future programs.

Question: How is the USGS's program on runoff erosion and sediment runoff related to similar programs by USDA?

Panel Response: The USGS Water Resources Division is actively involved in only two specific areas: (1) currently mined areas or future areas to be mined, plus, (2) the ongoing USGS widespread monitoring program covering all the Rocky Mountains Region and the Great Plains Area.

Question: Has any federal agency conducted any programs to determine the emissions of heavy metals, toxic elements and radionuclides from Western coals used in coal-fired power plants?

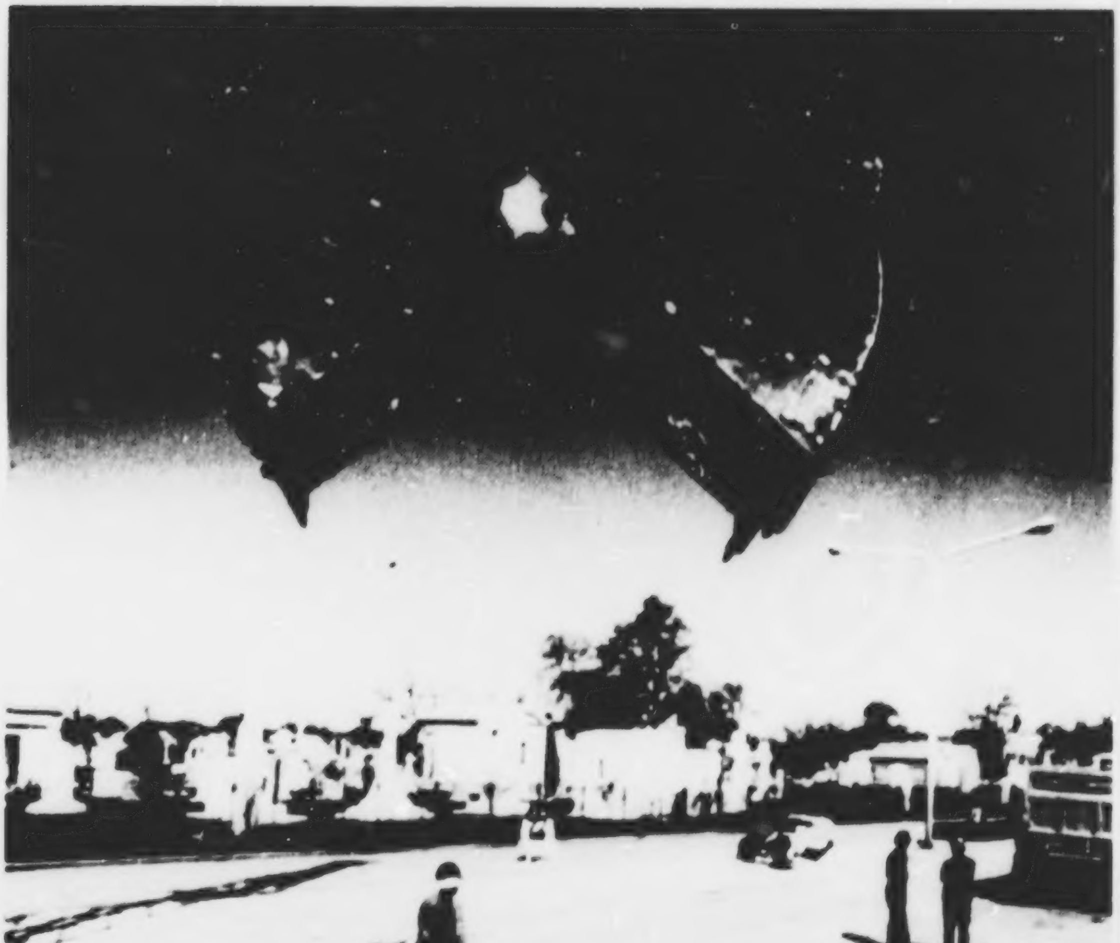
Panel Response: TVA is developing a residual output model but the elements that are to be included in the model are still being considered. Additional panel responses indicated that there appears to be extensive measurements already available on radionuclides and mercury in Western coal and that ERDA has an extensive program to determine the extent and fate of various constituents in coal.

Question: Are there any programs for monitoring and measurement which involve the large-scale analysis of human blood samples to utilize the human being as a means of monitoring for pollutants?

Panel Response: The program that can respond to that question is in the NIOSH exposure monitoring program that is described in Chapter 4.

CHAPTER 4

ENVIRONMENTAL HEALTH EFFECTS



INTRODUCTION

The number and variety of potentially toxic chemical agents to which occupational groups and segments of the general population can be exposed as a result of development of fossil energy conversion facilities is enormous. There are also many ways in which these agents may be encountered. This encounter may take place with gaseous pollutants, respirable particulates, waste liquids and solids, or the fuel products themselves.

The effects of pollutants or chemical agents may be classified as to the nature of their expected or suspected effect on human health. Such classification might reflect the toxic propensity for mutagenesis, teratogenesis, carcinogenesis or production of reproductive disorders, behavioral and learning anomalies, endocrine disfunction, organ toxicity and metabolic changes. The net result remains a complex problem of predicting and determining the identity and mechanism by which energy related pollutants exert detrimental effect on human health. This determination is essential to developing the strategies, technologies and priorities for control of energy related processes.

Research aimed at the objectives of protecting occupational and community health are being pursued by agencies in the energy, environmental and health fields.

Overview of NIOSH Energy Health Research Program

Kenneth Bridbord
National Institute for Occupational
Safety and Health
Rockville, Maryland

INTRODUCTION

It is a pleasure to represent the National Institute for Occupational Safety and Health today at this conference and to present an overview of our Institute's contribution to a national research effort relating to the health and environmental effects of energy technologies. The program to be described represents primarily the NIOSH contribution, an approximately $2.5 million annual research effort, in the area of health effects. This effort is being performed as part of a special multiagency R&D program related to energy coordinated by the Environmental Protection Agency. My presentation does not embrace the full spectrum of energy related research performed by NIOSH in its base program, much of which is supported under the Coal Mine Health and Safety Act. Coal mine health and safety research is an established NIOSH program with which I hope many of you are already familiar.

Before joining NIOSH, I served in one of the EPA research facilities whose mission included assessing the community health implications related to energy technologies. From my experience in both community health and now in occupational health, it has become increasingly evident that the occupational and community health problems associated with energy technologies are real, are important and are very much related to each other. The pollutants encountered in the community are frequently similar chemically to those which are found in the workplace. Further, the levels of occupational exposures are usually much greater than among the general population, making surveillance of working populations a mandatory component of any system designed for detection of early effects related to environmental agents.

DISCUSSION

In truth there is a continuum between occupational and community health. They cannot be viewed as distinct and separate entities. Data obtained from studies of workers, for example, may frequently be relevant to the community situation and vice versa. This is particularly true in the case of chronic health effects attributable at least in part to long term exposures to chemicals. Such effects are most easily studied among workers and when an excess risk among workers is found, we should assume that a similar but more subtle risk could occur as a result of community contamination.

There is no doubt in my mind that health considerations must play a major role in future policy decisions with respect to expansion of existing energy facilities and development of new energy technologies. In the past several years for example there have been increasing concerns as to the effects upon health of exposure to sulfur oxides emitted from power plants.

While I was at EPA, I participated in a multidisciplined effort to assess the health effects of community exposures to sulfur oxides. Our studies suggested that sulfur oxide gas per se may not be the primary health problem but that sulfur oxides might be converted to aerosols containing sulfur compounds which are potentially irritating to the respiratory tract. Studies related to effects of sulfates upon the respiratory tract and other organs are of course continuing. The data as they presently exist have, however, allowed policy makers to seriously consider the health effects of sulfates in making decisions regarding conversion of oil fired power plants to coal and in determining the siting for new power plants.

As we look further into the sulfur oxides questions we are likely to find that the problem is more complex than originally anticipated. Included in these concerns are the possible interactive effects between acid aerosols and other workplace and community pollutants including carcinogens. No doubt a considerable portion of our effort under the energy program will be directed to the sulfur oxides problem. In this regard we should not lose perspective that sulfur oxides may also pose a hazard in certain occupational groups as well.

Accordingly our Institute's research plans call for investigation of public utility and other workers exposed to sulfur oxides and sulfate aerosols for possible effects that such exposures may have upon chronic respiratory disease as well as mortality. In preliminary studies from our Salt Lake City laboratory it would appear that workers exposed to sulfate aerosols in combination with nitrogen oxides and hydrocarbon emissions associated with diesel repair work incur a 2 to 5 fold increased prevalence of chronic respiratory disease symptoms compared to similar age and smoking groups among the general population. Use of diesel engines in underground mining to increase our supplies of coal or to obtain needed raw materials for use in building new energy facilities, unless properly controlled, could present an important occupational health problem. NIOSH is investigating this situation in its base program.

By analogy to the sulfate problem there has been relatively little attention given to effects caused by other acid aerosols including nitric acid and nitrogen oxides. It has been estimated that emissions of oxides of nitrogen from stationery combustion sources contribute substantially to atmospheric loading by these pollutants. There is reason to believe that as with sulfur oxides and sulfates, chemical reactions in the atmosphere will lead to formation of new nitrogen compounds including new organic complexes. Such compounds have not been well studied as to their health effects and may pose an important health problem. Included in our suspicions related to effects of nitrogen oxide aerosols are the potential to aggravate preexisting cardiac and respiratory problems, possible decreased resistance to infectious agents and the possible role that such compounds may play in the development of chronic disease, including cancer.

Recently concerns have been expressed about chemical reactions between nitrogen oxides in the ambient air and amines to form nitrosamine compounds, a class of potential carcinogens based upon studies in experimental animals. While to date we have no documented cases of cancer in man from exposure to nitrosamines this may conceivably be explained by lack of adequate studies of such effects. Among the groups potentially at risk from such exposures are workers and there are at least theoretical concerns that nitrosamines could be an important exposure problem in coal gasification and liquefaction plants where simultaneous emissions of nitrogen oxides and amines are likely to occur. We also know that hydrazines are at times employed to control oxygen levels in coal fired power plants. Hydrazines themselves may be carcinogenic or may break down to form nitrosamines and again workers may be among those most heavily exposed. NIOSH is currently involved in a preliminary assessment of the hydrazine situation as part of its energy program and we are currently exploring ways to select appropriate working populations exposed to nitrosamines for long term followup study.

The potential for chemicals to contribute to the development of chronic disease including cancer appears to be a major public health problem and this potential must be addressed in any health research program related to energy. The consensus of many experts is that environmental factors play a major role in the etiology of cancer and that reducing exposures to carcinogenic chemicals in the workplace and in the general environment will likely have substantial public health benefits in the years to come.

Among the carcinogenic substances which may be related to energy processes are arsenic, beryllium, cadmium, nickel and chromium among the metals, vapor phase and particulate polynuclear aromatic compounds among the organics and asbestos and related fibers which are used in insulation materials. If one considers all the chemicals which have been identified as suspect carcinogens in animal test systems then the list of potential energy related carcinogens increases substantially. Clearly there are many lessons to be learned from our past experience including vinyl chloride which was once considered relatively safe. How many more surprises such as this are there likely to be in the future? Particularly in the energy area where the rapid expansion of existing and new technologies will impact many people, we need to examine closely the potential for these processes to cause adverse health effects before large capital investments are made.

A good illustration stems from our experiences with coke oven emissions. Here the evidence of carcinogenic risk, especially for lung cancer, is substantial. It is noteworthy that poorly contained coal gasification and/or liquefaction processes are likely to produce similar exposures as occur in coking operations. This is an area that requires significant effort not only to prevent long term effects in workers but in the general population as well. A concerted effort combining epidemiology and toxicology both in vivo and in vitro is required to adequately address this problem. With the development of rapid and increasingly more reliable in vitro test systems as possible predictors of carcinogenic activity, one may be able to selectively prioritize suspicious components in complex mixtures related to energy processes for further investigation. We should not lose sight of the interactions among chemicals which may be responsible for the ultimate biologic effect.

In this regard NIOSH is planning comprehensive morbidity and mortality studies of workers exposed during coal liquefaction and gasification processes to clarify the possible risk of life shortening illness and hopefully to identify the nature of emissions associated with the disease process. Our Institute's experience with the complex problems of coke oven emissions should hopefully prove valuable in such an effort. In a related area of concarn NIOSH is also evaluating the health experience of workers exposed to oil shale.

No discussion of energy related health problems would be complete without a consideration of energy conservation including the impact of such efforts upon worker health. For example, expanded requirements for new and existing insulation materials could mean increased health problems among workers engaged in the manufacture of these materials. Accordingly NIOSH has included a mortality study of workers exposed to insulation materials in its energy research program.

Energy conservation in residential and commercial buildings has been an additional suggestion to stretch our available energy resources. However, in our desire to conserve energy in residential and commercial buildings we may inadvertently be aggravating an existing or creating a new indoor air pollution problem. Recirculation of exhaust air to reduce heating or cooling of make up air is one conservation technique being considered. As part of the energy program, NIOSH is developing criteria for recirculation systems to eliminate potential occupational health problems. Decreases in the air turnover rate can have a major impact upon the concentration of a given pollutant when there exists an indoor source for that pollutant.

Among the sources of indoor pollutants which are particularly worrisome are halogenated hydrocarbons from aerosol products and solvents, nitrogen oxides and carbon monoxide from gas stoves and space heaters, sidestream cigarette smoke, hydrocarbon emissions from cooking, off gas products from plastic materials and asbestos fibers present in duct work and other construction uses. Here, too, there may be important occupational health problems. Recently available data suggest elevated concentrations of asbestos inside office buildings. If air turnover is decreased, this would potentially increase the level of contamination by asbestos.

Also present in the indoor environment of commercial buildings is sidestream cigarette smoke. We know from studies of workers exposed to asbestos that the risk of lung cancer is greatly increased among smoking asbestos workers. The possible health implications for millions of office workers potentially exposed to asbestos and sidestream cigarette smoke is unknown but of substantial concern. NIOSH is currently conducting a preliminary evaluation of this situation as part of its energy effort. Another conservation effort being investigated by NIOSH involves the possible hazard to workers in situations where waste materials are used as supplemental fuels.

Any efforts to reduce ventilation in industrial situations as a means to conserve energy must also be considered in conjunction with the possible ensuing health implications. Even if such conservation efforts were not to violate any existing health standard this action could potentially increase health risk to employees by increasing exposure to a given agent, particularly when long term low level exposure to that agent may be associated with increased risk of developing chronic disease.

Before closing, I should also note that NIOSH is conducting research directed at the development of countermeasures for the protection of energy industry workers. The initial effort in this area has been primarily directed at commercial divers involved with offshore oil. In the area of countermeasures, I should also point out that a considerable portion of the effort in this national research program is being directed toward the development of control technology to reduce community exposures to energy associated pollutants. A portion of that effort should be directed to develop control techniques for reducing worker exposure as well.

Additionally, I might mention that NIOSH is developing various devices to measure and monitor the occupational environment for energy industry related pollutants, which will be described in more detail later at this conference. I should also add that our Institute is endeavoring to maintain as flexible a posture as possible so that we may respond to newly emerging occupational problems related to energy. In this regard mechanisms are being worked out to identify and respond rapidly to new potential energy associated problems.

CONCLUSIONS

The rationale for NIOSH's energy health research effort has been presented. Unless the health and safety of workers in energy related industries can be assured, this will be an important limiting factor in our nation's ability to achieve energy self-sufficiency.

HEALTH EFFECTS RELATED TO EMERGING ENERGY TECHNOLOGY

John H. Knelson, M.D.
Health Effects Research Laboratory
EPA - Research Triangle Park, NC

INTRODUCTION

The energy-related health effects research program being conducted by EPA in Research Triangle Park, NC, is primarily oriented to technologic changes anticipated for the near-future. These include major conversion from oil and gas to coal combustion, coal gasification and liquefaction, shale oil extraction, increased nuclear power production, and decreased energy use for transportation. The Health Effects Research Laboratory in North Carolina (HERL/RTP) is the major focus of EPA's resources in epidemiology, clinical research, and toxicology being used to assess the relative public health impact of alternate energy-producing technologies. Research conducted by EPA's Cincinnati Health Effects Research Laboratory is carefully coordinated with that of HERL/RTP.

TECHNIQUES

The objective of the administration of HERL/RTP is to conduct a balanced program of intramural and extramural research, coordinating work on high priority EPA problems with the nation's high priority of energy independence. Thus a significant part of the HERL/RTP "base" research program under the Office of Health and Ecological Effects is tailored to complement that part performed under the aegis of the Office of Energy, Minerals, and Industry (OEMI).

This research program is organized along disciplinary lines, with various categories of pollutants investigated using many techniques, resulting in a matrix approach to problem-solving.

The Population Studies Division conducts community studies by measuring environmental factors to assess population exposures and relate them to the health status of those populations. Their energy-related work is largely oriented toward the relationship between levels of sulfur oxides, nitrogen oxides, and trace metals to cardio-respiratory disease experience in populations of various age groups and special susceptibilities. A new program of mortality studies has been initiated to relate death by specific cause (especially specific neoplasms) to industrial as well as demographic data by area of residence.

The Clinical Studies Division conducts a coordinated program of animal and human studies. A major national resource, developed over the past five years, allows sophisticated simulation of urban atmospheres in two large controlled environmental laboratories designed for human clinical research. Addition of aerosol generating and monitoring equipment to one of these laboratories will permit controlled clinical studies of human health effects of airborne respirable particulate matter as well as gaseous pollutants. The particulate matter of most concern in this program is water soluble sulfates.

In addition to the controlled environmental laboratories, two mobile laboratories equipped with nearly identical cardiopulmonary physiologic and computerized data acquisition equipment are nearing completion. These mobile physiologic laboratories will be used to study specific problems, such as those in the vicinity of a power station converting to coal burning, by teams of scientists from the Population Studies as well as Clinical Studies Divisions.

The Environmental Toxicology Division incorporates resources for a wide range of basic toxicologic evaluation of complex organic molecules expected to result from coal conversion and shale oil extraction. Multi-route exposure facilities for animals ranging from rodents to primates exist. Toxicity screening systems employing the basic techniques of histopathology, metabolism, and physiology have been advanced in these laboratories over the past several years. In vitro mutagenicity testing systems using mammalian cell lines complement the basic toxicology techniques. Sophisticated biochemical and analytic methods development capability are used in support of the toxicity testing programs of this Division.

The Experimental Biology Division has conducted a series of studies over the past several years directly related to energy production. These consist of animal toxicity testing of tritium and krypton-85 which result from nuclear fuel reprocessing. In addition, this Division conducts all animal neurobiology and reproductive studies for HERL. It is expected that many of the effluents from emerging energy technologies will pose hazards that must be carefully evaluated in these test systems. Animal resources are provided by this Division, assuring the integrity and quality of all animal experiments throughout the Laboratory.

PROGRAMS

The seven components of the HERL Energy Accomplishment Plan are listed, and their coordination with the described discipline/pollutant matrix is discussed:

Evaluate, via *Clinical* and *Epidemiological* studies, Effects in *Normal*, *Susceptible* and *Stressed* Population Groups, from Exposure to Effluents Associated with Coal Conversion and Utilization.

Determine the Dose-Effect Relationship for *Behavioral*, *Physiological*, and *Metabolic* Effects resulting from Exposure to Effluents from Coal Utilization and Conversion Sources.

Develop More Sensitive and Rapid *Cytological*, *Biochemical* and *Physiological* Indicators to Establish Dose and Damage to Man from Effluents related to Coal Conversion and Utilization.

Identify *Carcinogenic*, *Mutagenic*, *Teratogenic*, and other Toxic Substances related to Coal Conversion and Utilization using *Biological Screening Systems*.

Determine the Dose-Effect Relationships for *Behavioral Teratological*, and *Carcinogenic* Effects Resulting from Exposure to Effluents from *Nuclear Fuel* Utilization and Processing.

Evaluate the Health Implications Resulting from Exposure to *Indoor Air Pollutants* as These Relate to Energy *Conservation* Measures Reducing Indoor/Outdoor Ventilation.

Evaluation of Potential Toxic Hazards Arising from Extraction, Processing and Utilization of *New Energy Sources* such as Shale Oil.

COAL CONVERSION AND UTILIZATION

Evaluation via clinical and epidemiologic studies of effects in normal, susceptible and stressed population groups is being conducted by the Clinical Studies and Population Studies Divisions working together. The major effort here is concentrated in completion and improvement of facilities for population exposure assessment and controlled environmental laboratory clinical research, as well as operation of the mobile physiologic laboratories. Cardio-pulmonary disease experience, changes in cardio-pulmonary physiology, immune and metabolic status as well as neoplastic disease experience all associated with effluents from coal conversion and utilization are being studied in this aspect of the Energy Program. Funding from OEMI in this area is $2,100 K.

Determination of dose-effect relationships for behavioral, physiologic and metabolic effects is being conducted using many of the techniques described with respect to the clinical and epidemiologic research. In addition, animal and clinical studies have been initiated specifically to determine the relative toxicity of sulfates having different cationic components. OEMI funding for these studies is $240 K.

Development of more sensitive and rapid cytological, biochemical and physiologic indicators has been given high priority in the overall program of HERL. Expansion of the mammalian cell line *in vitro* test system is in progress. Studies of metabolic alterations that will serve as bioindicators to quantify sulfur oxides and nitrogen oxides exposure in man are underway. Significant improvements in non-invasive assessment of cardiac function are being developed in HERL by computer techniques applied to ST segment analysis, systolic time interval determination, and myocardial mechanical function measurement using ultrasound. OEMI funding in this area is $400 K.

Carcinogenic, mutagenic, and teratogenic screening systems are being developed or are already in use to study interactions between fibrous amphiboles and other potentially co-carcinogenic material, benzo(a)pyrene in the isolated perfused lung, interaction between known pulmonary carcinogens and fine sulfuric acid aerosol, as well as *in vitro* toxicity testing of crude airborne particulate matter filtered from urban atmospheres. In addition, *in vitro* screening of selected air pollutants for chemically induced neoplastic transformation is being conducted. OEMI funding in this area is $1,200 K.

NUCLEAR FUEL UTILIZATION AND PROCESSING

Long-term exposure to tritium to determine effects on growth and development, especially of central nervous system function, are in progress. In addition, HERL is conducting research to identify a population of laboratory rodents with particular sensitivity to tritium induced neoplasia. Prolonged exposure to krypton-85 under [illegible]-infinite cloud conditions has been initiated. OEMI funding in this area is $500 K.

ENERGY CONSERVATION AND THE INDOOR ENVIRONMENT

A modest program to characterize the indoor (home, office, school, non-industrial workplace) environment through inventory of household products as well as indoor/outdoor air quality assessment is in progress. The focus of this effort is to characterize and assess the health implications of air pollution levels in the indoor environment with particular attention given to those sources of pollution which originate indoors. Examples include exposure to chemicals from aerosol products, solvents, cigarette smoke, cooking and insulation materials (i.e., asbestos and asbestos-like fibers). Where relevant, health information will be sought from occupational groups with exposures that resemble those found in the indoor home environment, i.e., cooks, cosmetologists and workers in dry cleaning establishments. A model will be developed to predict exposures and project potential health effects. OEMI funding for this program is $200 K.

TOXICITY OF PRODUCTS ARISING FROM NEW ENERGY SOURCES SUCH AS SHALE OIL

The initial activity in this area is the establishment of a chemical respository for materials likely to be generated from New Energy Sources. Following establishment of and standardization of the repository, toxicity screening tests such as those described for coal combusiton and conversion processes will be initiated. OEMI support for these studies is $825 K.

CONCLUSION

The resources, priorities, rationale, techniques, and specific approaches to the problem of health evaluation of emerging energy technologies has been summarized. All funding for HERL/RTP programs from OEMI have been FY 1975 figures. The total is $4,515.4 K. It must be realized that shifts in funding level must occur as the programs evolve and new problems as well as opportunities arise. Therefore these figures are meant to reflect relative level of effort and may not remain accurate.

The Energy Program for FY 1976, as would be expected, is closely related to and extends that of 1975. The total level of funding anticipated from OEMI is $4,037 K. Because such a large fraction of the non-energy related portion of the overall HERL/RTP program supports in one way or another that part funded by OEMI, it is impossible to ascertain with any precision the total energy-related budget. This seems inevitable in a highly integrated interdisciplinary program.

HIGHLIGHTS OF NIEHS ENERGY-RELATED RESEARCH

Dr. Robert L. Dixon
National Institute of Environmental Health Sciences
Research Triangle Park, North Carolina

INTRODUCTION

NIEHS activities focus on a number of toxicology subdisciplines essential to the understanding and assessment of potential toxic effects of environmental factors on human health. These include: 1. Indicators of toxicity; 2. Biochemical mechanisms of toxicity; 3. Mechanisms of incorporation, metabolism, disposition, and turnover; 4. Dose-effect relationship for toxic effects; 5. Extrapolation of laboratory models to man; 6. Mutagenesis, developmental toxicity, and carcinogenesis.

These concepts support and evolve from studies of a wide spectrum of externally-derived bioactive chemical and physical agents. Those related to energy production and conservation activity are of special importance. Broadly these can be categorized as: 1. Gaseous air pollutants; 2. Suspended particulates; 3. Industrial by-products and intermediates; 4. Trace metals; 5. Physical factors.

An attempt has been made to briefly describe highlights of these activities. The impossibility of defining precise categories accounts for the obvious overlaps between these two general activities.

1. Indicators of Toxicity

Efforts are being made to develop reliable in vitro and in vivo systems for the measure of toxic effects induced by energy related hazardous agents. The focus is on tests designed to both identify and quantify a wide variety of agents and effects. Efforts are being applied to improving systems for rapid prescreening. However, the major emphasis is on mammalian systems which will facilitate translation of test results to man.

In vitro cells and tissues and lower animal test systems offer the possibility of reliable toxicity test systems which are more rapid and less expensive than whole animal tests. Blastocysts, prenatal ovarian tissues, and bone marrow cells in culture as well as a number of more routine cell lines are currently being studied.

2. Biochemical Mechanisms of Toxicity

NIEHS is supporting efforts to compare effects of toxic agents on various systems of differing biological complexity so as to identify key sites involved in producing toxic effects as well as to validate use of simpler test systems in understanding the site and mechanism of action of toxic chemicals. Test systems range from isolated organs, through tissue slices or cultures to intracellular organelles, isolated enzyme systems, and purified macromolecules. Toxic agents include air and water pollutants whose sources are primarily energy-technology derived. These studies provide important knowledge of initial or early cellular lesions.

A great deal of laboratory research is ongoing which seeks to improve our understanding of toxic mechanisms and provide improved test systems. The reliability of the extrapolation of laboratory animal data to man must be demonstrated in a conclusive manner. Model systems which incorporate pharmacokinetic parameters should eventually allow a more exact extrapolation to the human population.

3. Mechanisms of Incorporation, Metabolism, Disposition, and Turnover

A number of studies are being supported to determine the mechanisms of incorporation, metabolism, deposition, and turnover of energy-related hazardous agents. Pharmacokinetic aspects of inhaled, orally absorbed, and local exposure are being investigated. Absorption studies to determine the permeability of biological barriers that separate the blood (or critical tissues) from the external environment are important. Metabolism studies must include a careful consideration of both activation and degradation mechanisms. The biological distribution of agents is being studied with special emphasis on "barrier protected" tissues, e.g., central nervous system, testis, fetus. The deposition, storage, and translocation of agents need to be investigated as well as their pulmonary, hepatobiliary, and/or renal excretion.

Studies are being undertaken to characterize the processes involved in transfer of energy-related hazardous agents from particulates to body tissues and fluids. This necessitates the development of methods for generating well-defined aerosols containing particulates of different sizes and hazardous chemical "load."

4. Dose-effect Relationship for Toxic Effects

Studies are being supported to consider the dose-response relationships for biochemical and toxic effects of energy related agents. Major organ toxicity is being determined as well as the predictiveness of clinical signs and the reversibility of toxic lesions. Effects on behavior, blood and other body fluids, liver, nerve-muscle, kidney, respiration, circulation, endocrine function, reproduction, etc., are being studied. A comparison of acute, subchronic, and chronic effects are being made as well as consideration of both prenatal and postnatal exposure.

5. Extrapolation of Laboratory Models to Man

Mathematical and statistical methods are being developed for the extrapolation of animal and cellular data to man for low dose risk estimation. Both stochastic models of the carcinogenic process and statistical techniques pertinent to extrapolation are being studied. Attention is also being focused on the problem of species-to-species variability. As part of this effort, existing data bases are being reviewed and evaluated to determine if they can be used to make meaningful interspecies comparisons. In addition, new data sources that can be utilized to quantify species-to-species variability are being produced.

6. Mutagenesis, Developmental Toxicity, and Carcinogenesis

Mutagenesis. Methods by which the frequency of somatic point mutations at several genetic loci in experimental animals and human beings can be measured are being developed. Detection of mammalian somatic mutations provide advantages in mutation research for the following reasons: (1) human cell samples could possibly be used for the study of mutation rates in man, (2) in mutagenic test systems, the animal's own cells would be used, which would avoid the immunological reactions occurring in the host-mediated assay, and (3) chronic studies of compounds in low doses could be initiated.

Point mutations in male germinal tissue are being studied. The purpose of this investigation is to develop methods by which point mutations can be detected directly on spermatogonia, spermatid, and sperm. The mutant cells are being detected by differential histochemical stains. Several enzyme systems are being employed, some common for somatic cells and the germinal tissue, some specific for the sperm.

Sperm samples are relatively easy obtained in the human population and these methods can be used to monitor the human population for the mutation rates and possibly detect fractions of the population at high risk.

It is generally felt by geneticists that an increase of the mutation rate in the human population would be detrimental, yet there is no system developed to monitor the human population for point mutations.

A system for mutagenicity testing using a tier concept facilitates the assessment of potential hazards associated with human exposure to drugs and other chemicals. The proposed system is a hierarchical system containing three tiers or levels of testing. Using relatively rapid and inexpensive in vitro microbial tests, the first tier will serve as a prescreen to determine priorities for further testing. Tier two assesses mutagenicity in more complex systems involving higher organisms. Tier three considers mutagenic compounds from tier one and two and is designed to give quantitative results about mutagenic effects on mammals under defined use conditions.

NIEHS is supporting EMIC to compile the past and present literature on mutagenesis testing of energy related pollutants. This information is then processed into EMIC's data bank noting bibliographic details and keywording of chemicals, organisms, and systems studied, and is available to investigators throughout the world.

Developmental toxicity. Ongoing studies include assessment of the effects of environmental agents on oogenesis and spermatogenesis. Longer term objectives include a much more expanded effort to identify environmental factors which account for male and female infertility. Close working relationships are being established with infertility clinics and scientists working in the area of epidemiology.

The NIEHS is seeking to develop mechanisms for the selection of environmental chemicals for teratogenicity testing and to establish priorities for testing. Standardization of test protocols is an important aspect in the conduct of the actual testing which is performed by contract. A new teratology information service is also being designed to bring together the world's literature on teratology. Longer term objectives involve the use of "embryo culture" to study the mechanisms of teratogenic effects and perhaps develop methods to rapidly predict human teratogens.

Current studies with DES emphasize the unique sensitivity of the embryonic period with regard to chemical insults which result in infertility and perhaps cancer later in life. These "biological timebomb" areas include, in addition to reproductive and carcinogenic effects, potential toxic effects on nearly all biological and physiological functions. An area which we consider to be of primary importance relates to the latent effects of gestational chemical exposure on physiologic functions, such as cardiovascular and behavioral responses.

Carcinogenesis. Laboratory and clinical studies related to carcinogenesis are described in the following section.

As mentioned previously, bioactive chemical and physical agents from energy production and conservation activities can be grouped into five broad categories. These categories are used in the following account of research highlights.

1. Gaseous Air Pollutants

Nitrogen dioxide and ozone. Important contributions are being made by a number of NIEHS-supported investigators toward understanding the etiology, pathogenesis, and other relations of NO_2 and O_3 to pulmonary and extrapulmonary disorders.[1] Rats exposed intermittently for a lifetime to 15 ppm NO_2 develop a chronic obstructive lung disease with features much like those of human emphysema. O_3 was shown to be approximately 20 times more injurious than NO_2. The disease it induces is similar to that caused by NO_2, but there are certain significant differences.[2] Insight into the molecular bases of cellular injury is being provided by a number of investigators.

In addition to effects directly on lung tissue, a number of studies show that O_3 and NO_2 produce other kinds of toxicity as well.[3] Macrophages are damaged by exposure to 25 ppm NO_2 which reduces the in vivo bactericidal capacity of alveolar macrophages. Thus, in addition to direct damage to lung tissues, individuals exposed to the gases may become prone to infectious pulmonary diseases.

Sulfur oxides. A considerable body of evidence suggests that there may be discernible human health effects from exposure to concentrations of sulfur oxides approximating the current standards.

Several projects are being supported by NIEHS to gain further information about the effects of sulfur oxides on selected populations and the distribution, fate, and reactions of sulfur oxides in the body. A study was initiated this year on the deposition and effects of sized sulfuric acid droplets in the lungs. Epidemiologic data are being collected from selected sites to determine the effects of particulates and sulfur oxides in combination on adults and children.

Automobile exhaust. Epidemiological and aerometric studies have been conducted over the past several years. Personal monitoring of carbon monoxide, nitrogen dioxide, respirable mass total particulates, and respirable mass lead particulates is being initiated.

The second year of environmental sampling of tunnel-turnpike workers is now being completed. The environmental measurements focused mainly on the toll booth operators' exposure to automobile exhaust at three toll plazas. Air sampling is conducted for nitrogen dioxide, carbon monoxide, total hydrocarbons as methane, respirable and total suspended particulates, and lead in both the total and respirable fractions. As yet, no significant differences in mortality, pulmonary disorders, or cardiovascular disease of these workers are being evident when compared to controls exposed to lower levels of automobile exhausts.

Carbon monoxide. NIEHS supports a substantial number of epidemiological and basic studies designed to provide a better understanding of the extent and nature of the hazard presented by inhalation of carbon monoxide alone and in combination with other toxic agents.

Many aspects of carbon monoxide distribution and intoxication are being studied. It is generally agreed that one of the more important effects is the reduction in oxygen-carrying capacity of the red blood cells which results from preferential binding of CO to the oxygen binding sites of hemoglobin. Epidemiological studies of cigarette smokers show that 35 to 40 percent of the hemoglobin may be in the form of carboxyhemoglobin during periods of heavy smoking.

The consequence of reduced oxygen carrying capacity is variable from individual to individual and is related to other disorders. Patients with circulatory insufficiencies and with various forms of anemia are most susceptible to physiological disorders resulting from oxygen insufficiency, and data are now available which show significantly higher mortality rates in smokers with circulatory and blood disorders.

CO effects other than a simple reduction of oxygen-carrying capacity of the blood are also becoming evident. It is being shown that CO combines with muscle myoglobin, cytochrome oxidase, cytochromes A_3 and P-450, catalase and peroxidases, i.e., many cellular constituents containing the heme moiety. There are also possible behavioral effects of CO at low levels. Long-term studies suggest that moderate CO levels eventually lead to effects on the central nervous system which may not be due simply to the decreased oxygen-carrying capacity of the blood.

Benzene and other solvents. It is estimated that more than 2 million people are exposed to benzene and related solvents to a substantial degree. NIEHS supports several projects toward localizing and understanding the toxic action of industrial solvents. Metabolic studies in mice suggest that one major metabolite, e.g., phenol, is formed from benzene in the body and that the compound is rapidly excreted in the urine as the sulfate or glucuronide conjugate. Metabolism is stimulated by pretreatment with microsomal enzyme inducers, such as phenobarbitol, or by benzene per se.

2. *Suspended Particulates (Aerosols)*

Model studies. Because of the ubiquity of hazardous aerosols and their importance in man's health, a great deal of effort is being supported to elucidate the interrelationships of particle size, composition, and deposition to various respiratory disorders.

Particle clearance. While much of the particle deposits in the lungs are cleared within 24 hours of exposure, considerable material remains uncleared for prolonged periods thereafter and can be detected in the lungs even a year later. It is also being shown for the case of iron oxide that residues of the inhaled particles subsequently become stored as hemosiderin-like deposits in macrophages widely distributed throughout reticuloendothelial tissues of the body. In the lungs, particle clearance was found to occur predominately by way of the bronchial passages. Novel approaches are being developed in attempts to standardize mammalian test systems for the study of respiratory tract clearance.

Recent studies have shown that many toxic trace elements and compounds such as lead, cadmium, zinc, bromide, sulfate, and benzopyrene are present in respirable aerosols. It is also being shown that trace metals are extracted more efficiently by the body from these small respirable aerosols. Finally, airborne particles most likely to adsorb materials are of a size that is most likely to penetrate into the deep lung.

Effects of inhaled particles on macrophages. Most respiratory disease is either initiated by, or at least complicated by, the inhalation of particles and gases. Emphysema, bronchitis, pneumoconiosis, neoplasms, and infectious diseases all may be consequent to inhalation of obnoxious particles. The severity of resultant disease may be influenced by the number of particles deposited as well as their site of deposition and their ultimate fate. The pulmonary macrophage is being emphasized since it is a central figure not only in clearance processes but in the pathogenesis of some lung diseases as well.

Pathogenesis and epidemiological studies. Epidemiological studies on industrial dusts such as granite and talc have been underway for several years. A prospective study of 633 granite workers exposed to quartz dust is in process. It is found, as might be expected, that those workers who have the greatest exposure have the greatest loss of pulmonary function.

Asbestos. Perhaps the most important particulates from the standpoint of numbers of people seriously exposed is asbestos. Intensive and wide-ranging investigations into this problem continue by a number of investigators. A major portion of this work is devoted to obtaining information concerning aspects of environmental asbestos disease, including disease associated with household exposure, disease among residents living near asbestos plants, and disease in the general community. An important aspect of the studies on asbestos and other particulates as well is the relationship of cigarette smoking to disease risk. A significantly increased risk of death of bronchogenic carcinoma among asbestos workers is being well established.

Soot, carbon black, and benzo(a)pyrene. Several projects are being supported on the relationships between soot and associated benzo(a)pyrene and other carcinogens. These studies assume increased importance in the use of low grade fossil fuels, especially in conjunction with cigarette smoking.

Some calculations are already being completed, and results indicate that heavy occupational exposure to benzo(a)pyrene is associated with increased mortality from lung cancer. Of course, since the fumes from hot pitch contain various other agents in addition to benzo(a)pyrene, the findings in this study could be due to one or more of the other factors or to their combined effect.

An extensive study of the health status of printing trades workers, exposed to carbon black (as well as other substances) is being initiated. Simultaneously, an epidemiological mortality study is being conducted. It is expected that these studies will provide information useful in the assessment of carbon particles in other trades and occupations and in the general population.

Coal dust. Extensive studies on the pulmonary effects of coal dust and the role of specific components of the dust in the etiology and pathogenesis of pneumoconiosis are being conducted. Correlates between the incidence of pneumoconiosis in miners in Pennsylvania and Utah show that the former is significantly higher, which is in accord with the high nickel and iron contents of the coal.

3. Industrial By-products and Intermediates

Though a multitude of chemical agents may be viewed as peripherally energy-related, a few directly associated with manufacture of insulation, use of heat transfer agents, and power transmission are of particular concern.

Since many polymers are used in energy related activities, intensive studies are underway in a number of laboratories of monomeric intermediates. These include bis(chloromethyl)ether and its homologues, vinyl chloride, and other chlorinated alkanes and alkenes, certain amides, diisocyanates, styrene, and related compounds.

Bis(chloromethyl)ether. Bis(chloromethyl)-ether has been identified as a potent carcinogen for skin. Its high activity for the lung is also demonstrated. Cases of lung cancer are now being found in industries using this compound. An industry-wide epidemiological study to develop definitive information on the health consequences of its industrial use is being conducted.

Vinyl chloride and related compounds. Health effects of vinyl chloride are being investigated in several laboratories. Over 1,200 polymerization workers employed by three companies in the United States are being examined.

Studies on structure-activity relationships of chlorinated alkylating agents to carcinogenicity have led to identification of important parameters in carcinogenic activity. It might soon be possible to predict with some confidence the carcinogenicity of compounds within this class. Studies concerning hepatic angiosarcomas are being extended.

Studies are also being initiated on the mutagenicity of vinyl chloride. It is found that the mutagenic effect of vinyl chloride is enhanced by mouse or rat liver extracts. However, extracts from mice pretreated with vinyl chloride or with the potent enzyme inducer polychlorinated biphenyls are no more effective in enhancing VC dependent mutagenesis than extracts from untreated animals.

The hazard of vinyl chloride has led to increased concern about many related haloalkanes and alkenes. The recent announcement of carcinogenicity of trichloroethylene in animals has raised the question whether this potential carcinogen increases cancer risk in humans.

Styrene oxide has been found to be mutagenic in animals. It is under further study, along with its metabolites.

Toluenediisocyanate. Studies on molded foam workers are being continued. The data now show that there is a significant decrease in the ventilatory capacity of all workers in the plant during the working day.

Nitroso compounds. Because of the mutagenicity of N-nitroso compounds as a class and the possible formation of such compounds from nitrogen oxides, many projects dealing with these compounds are being supported by the NIEHS. Individuals may be exposed to nitroso-compounds through a wide variety of possible sources. In each of the exposure circumstances described, evaluation is being made of the number of individuals potentially exposed, and of possible epidemiological procedures for further studies.

Polychlorinated biphenyls. Polychlorinated biphenyls (PCBs) are a group of chlorinated organic compounds, of which some 200 homologues are known. About 100 have been identified. Mixtures of PCBs are important industrial products. Prior to the environmental concern about the persistence and accumulation of the compounds, they were used in a wide variety of applications in commerce. However, beginning in 1971, their use was restricted.

Research in several laboratories designed to further our knowledge of the persistence and metabolism of the PCBs, the mechanisms of [illegible] and carcinogenesis, and the mechanism of long-term reproductive effects is being supported.

4. Trace Metals

Trace metals constitute a [illegible] class of pollutants. Though the [illegible] mercury and their compounds, [illegible] increasing on cadmium, chromium, copper, manganese, arsenic, and some of the rare earth elements.

Mercury. Studies of human occupational exposure to elemental mercury vapor are continuing. Following almost complete retention of vapor in the lung, it is excreted from the body slowly with a biological half time of about 58 days. This indicates that workers occupationally exposed to the vapor continue to accumulate the metal for about one year. From the practical point of view, blood and urinary mercury levels would not be a useful index of exposure until the worker had been employed for one year.

Studies on volunteers also reveal a new pathway of excretion of mercury in man. Significant amounts (about 7 percent of the inhaled dose) are excreted from the lungs as volatile mercury. The data suggest that measurement of exhaled mercury could be used as an index of recent exposure to mercury.

Prenatal low dose methylmercury in the chicken and rat produces lasting effects. Exposure early in development renders the chick more sensitive to chemically and electrically induced seizures and less capable of learning tasks when compared to controls or older embryos injected with the same or lower doses at a later stage of development. The effects of mercury on the cytology of the central and peripheral nervous system is being studied in mammals.

Attempts are being made to define further the effects of congenital chronic low-dose exposure of the rat fetus. During the past year, testing of a group of adolescent Rhesus monkeys given small daily doses of methylmercury to establish a chronic dose-response baseline was completed. All of the animals were tested on a behavioral task which is sensitive to changes in the peripheral visual fields and to eye-hand coordination. Further, their general cage behavior was observed, and movement disorders, when they occur, were documented with videotape. These studies indicate that chronic exposure for up to one and one half years at blood levels below 2.0 ppm do not produce obvious symptoms in adolescent Rhesus monkeys. When the blood levels were gradually raised between 2.0 and 2.5 ppm, all of the animals exhibited a rapid onset of neurological symptoms. Although the exact constellation of disorders differed somewhat between animals, there were radical changes in emotional behavior, anorexia, loss of fine control of the digits, and inefficient mastication.

Lead. Lead in its various environmental forms continues to be a major concern, and numerous projects are supported by NIEHS on various aspects of the problem.

Attempts are being supported to develop techniques for measurements of free erythrocyte porphyrins (FEP) on blood samples collected on filter paper and evaluate the clinical significance of FEP elevation in regard to both Pb intoxication and Fe deficiency anemia. The molecular mechanisms of protoporphyrin binding in both Pb intoxication and erythropoietic protoporphyria is also to be studied.

Studies on the role of lead in brain dysfunction are being supported. Under conditions of chronic ingestion of relatively low levels of lead from birth to adulthood, leading to increases in brain lead content and altered states of behavior, dopamine metabolism is either unchanged or partially slowed. Norepinephrine turnover is increased by as much as 30 percent and leaves the brain 14 percent more rapidly in lead-treated animals than in controls. Whether the increased turnover of norepinephrine is causative or associative to the experimental conditions under study is unknown. Effects of chronic, low-level lead exposure on the behavior of developing rats is being examined.

Exposure of newborn mice to lead in the milk they receive during nursing from mothers given lead in their drinking water results in a hyperactivity that persists for extended periods of life. These hyperactive mice exhibit no other overt symptoms of lead intoxication. Thus, this type of behavioral abnormality represents a very sensitive indicator of lead toxicity. As with hyperactivity in children, this animal model of hyperactivity responds paradoxically to amphetamine and phenobarbital. Attempts are being made to determine the lead levels and stages of development of the rat at which the brain is sensitive to damage, using both biochemical and behavioral parameters.

Trace metals affect experimental infections. Administration of lead augments the severity of *Candida* and *Listeria* infections in mice. No such augmentation of staphylococcal infections is found. These findings occur at various lead levels, including those comparable to blood concentrations found in man.

A number of investigators are attempting to design agents useful for clearance of heavy metals from the body and therapy of intoxications. Several classes of possible heavy metal binding agents are being examined by use of a computer. Each class is based on a naturally occurring compound. The most interesting class so far has been the steroids.

Cadmium. Cadmium is under investigation in several projects supported by NIEHS. Attempts are being made to develop a clearer picture of body levels of cadmium relative to specific disorders, using the rat as a model. Blood pressure of male rats on a basal diet containing a large amount of Cd (150 ppm) increased gradually from about 115 mmHg to 150 mmHg after 16 weeks exposure.

In addition to effects on blood pressure, it is found that Cd affects the humoral immune system, and the effects are detectable well before any overt signs of Cd toxicity. The implications of these events in the breakdown of resistence to infectious diseases are profound and are being investigated further.

The teratogenic effects of mercurials, lead, chromium, and ytterbium are also being explored. The major manifestation of embryonic damage with inorganic mercury includes an increased resorption rate as well as an increased frequency of small, retarded, and edematous embryos. Comparative studies on the teratogenicity of chromium and lead show that the metals have similar effects and that mixtures of the two are additive.

5. Physical Factors

There is growing concern about the effects of noise, microwaves, laser radiation, light, and other physical factors on human health. The many ramifications of physical factors on health remains a relatively little studied area.

Heat. Attempts are being made to assess heat stress. Effort is being devoted to understanding the physical characterization of the thermal environment in terms of a useful index of heat stress and of heat strain.

Light. NIEHS is continuing to support studies of effects of physical factors on the endocrine system. The influence of light on hormonally-controlled processes in mammals is being explored. The studies are concerned with the basic molecular events through which neuroendocrine effects are initiated and carried out. These studies provide probably the first available information on the action spectrum for any nondermatological or nonvisual effects of light on intact animals.

Studies involving laser radiation are in progress. Laser radiation has potentially significant therapeutic applications, but may also be a health hazard. Research is concerned with establishing an understanding of the mechanisms and consequences of laser excitation at the molecular level. Work has recently begun on the laser photolysis of visual pigments and related compounds.

Other studies are continuing on several aspects of the biologic effects of light. Concern is growing recently about possible alteration of the earth's atmosphere with resultant changes in the quality of light reaching the earth's surface. In addition, there is concern about the plethora of photoactive chemicals to which the population as a whole is being exposed.

Skin cancer can now be induced reliably in animals by use of the new equipment and techniques. The techniques also provide predictive capability with respect to the consequences of diminishing atmospheric ozone and the interaction of light and chemicals in photocarcinogenesis of the skin.

Noise. Investigations on the ototoxic effects of lead and mercury in monkey are being supported. It is being demonstrated that ototoxicity of lead is not very great even at levels so high as to cause debilitation and death. Recent work on ototoxicity of methylmercury reveals severe changes in auditory processes, and the hearing losses extend well into the middle (4,000 H_z) and high tone (16,000 H_z) regions of the audio spectrum, with some threshold shifts greater than 85dB.

Electromagnetic fields. The increased use of nuclear power plants will undoubtedly be the initial approach toward meeting our energy requirements without further dependence on oil. Associated with these nuclear power plants will be transmission lines with projected voltages of 1100-1200 kilovolts (Kv). Most high voltage transmission lines used today are of the order of 300-500 Kv. Commercial power systems in the U. S. operate at a frequency of 60 Hz. The most often reported effects of electromagnetic radiation has been on the central nervous system. Effects of electromagnetic fields, similar in character and intensity to those resulting from high voltage transmission lines, on the central nervous system of mammals are being investigated. The effects on behavior are being studied and correlated with measured changes in brain rhythms and neuronal membrane structure.

The highlights obviously represent only part of the NIEHS research activities in the areas of environmental health science related either directly or indirectly to the potential health effects associated with the development and use of domestic energy sources. However, they do provide some indication, however sketchy, of the spectrum of research activities and interests of the NIEHS in this important new health area.

ERDA PROGRAM TO EVALUATE HEALTH-EFFECTS OF NON-NUCLEAR ENERGY TECHNOLOGIES

George E. Stapleton
Division of Biomedical and
Environmental Research
Energy Research and Development Administration
Washington, D.C. 20545

INTRODUCTION

Prior to the establishment of the Energy Research and Development Administration, most of the health effects program resided in the Atomic Energy Commission and encompassed primarily an evaluation of potential health problems associated with all aspects of the nuclear fuel cycle from extraction to processing to end use and ultimate disposal of radioactive materials. This program is continuing under ERDA but is not to be the subject of this presentation.

Rapid expansion of research and development under the ERDA plan is aimed at providing a number of choices for energy production from sources of non-renewable energy that still exist in abundance while at the same time maintaining the options for use of renewable sources. Heavy emphasis for the near-term is placed on fossil fuel sources. It is recognized by those responsible for the massive chemical and engineering development to provide substitute fuels that some major problems at advanced stages of development will be possible restrictions imposed by new or modified health and environmental protection standards and guidelines. It is now possible to provide the required quantitative health effects information in concert with large-scale industrial development and in a time frame consistent with it. This is the basis for the program described herein.

The nature of the fossil fuels program planned by ERDA provides an opportunity to treat the potential health problems associated with a variety of chemical agents common to a number of processes, for example, trace and heavy metals, in a generic sense. However, we must consider the unique health problems associated with each major technological process as decisions are made to expand from bench-top, to pilot and demonstration plant before full commercialization. A proper balance must be maintained in programming for research that addresses the generic problems associated with emissions and waste and those which address the product and byproducts of a specific process marked for rapid expansion to commercialization. The program now in place addresses potential health problems associated with several high priority coal liquefaction and gasification processes. The ERDA national laboratories provide the mechanism for organizing large multidisciplinary efforts ranging from sophisticated analytical chemistry to *in vivo* evaluation of dose-effect relationship in model experimental animals. Moreover, the ERDA-regional energy research centers involved in the chemical and engineering aspects of coal and shale conversion at the laboratory and small pilot plant scale provide much analytical chemistry as well as backup samples for biological testing. Some of the ERDA laboratories have developed expertise in specific disciplinary areas such as inhalation toxicology, aerosol physics and chemistry and *in vivo* metabolism and fate of toxic agents. These laboratories are conducting work in these specific disciplines to answer problems related to coal combustion and conversion and shale oil technologies.

TECHNICAL DISCUSSION

The number and variety of potentially toxic chemical agents to which both occupational groups and segments of the general population can be exposed as a result of development of large-scale fossil energy conversion facilities is enormous. Many of these agents are encountered in a number of ways, for example, as gaseous pollutants, combined with respirable particulates, in process and waste water, in waste residues or in products or byproducts of most of the planned processes for production of synthetic fuels from coal or oil shale. *In situ* processing of fossil fuels can overcome these problems but it is unlikely that large-scale commercialization of *in situ* processing will be feasible in the near-term.

Large-scale animal bioassay for toxicity as used today cannot provide a useful strategy to provide evaluation of the numerous individual chemical agents for the variety of damaging effects they might produce. Fortunately, the past several years has seen the development of a battery of rapid *in vitro* and *in vivo* biological screening techniques which can provide presumptive identification of carcinogenic and mutagenic agents. By use of such screens it is now possible to prioritize chemical agents and thus drastically reduce the number which must be subjected to the more elaborate, expensive and time-consuming animal bioassays to provide dose-effect relationships for mutagenesis and carcinogenesis. These rapid microbial and multitier screening methods combined with sophisticated analytical chemistry constitute Phase 1 of the ERDA health effects research program.

Although a number of screening methods are available to provide presumptive identification of mutagens and carcinogens, there are very few reliable or rapid methods that can be applied to either human or animal populations as early indicators of physiological damage or the progression of an already induced disease state. Availability of such early indicators would be a tremendous advantage in human clinical or epidemiological studies as well as in experimental toxicological studies. These efforts are now an important part of the energy related programs of NIEHS, ERDA and EPA.

At present, there is no simple and straightforward method to derive human risk estimates for late effects from model experimental animals, or from rapid *in vitro* screening methods. Carefully conducted dose-effect studies on several animal species plus accurately determined information on dose to the tissue at risk and innovative theoretical modelling appear to be the only plausible approach. A coupling of such efforts with whatever human clinical and epidemiological data that exist or become available comprise a logical approach to formulation of guidelines or standards for human exposure. All health agencies fund efforts in one or another or all of these aspects of research for pathophysiological, teratological, mutagenic and carcinogenic effects of energy-related chemical pollutants.

Ultimately a solution to some of the problems we presently encounter in attempting to extrapolate experimental data to man will come from basic understanding of both the fundamental molecular interactions that lead to cellular damage and the repair and recovery processes that compensate for the initial damage. Such efforts should constitute a fair share of any "balanced plan" to evaluate the health effects of chemical pollutants. It is also important to recognize that such studies have been and will continue to supply new useful systems for "rapid" screening of environmental pollutants.

PROGRAM DISCUSSION

Interagency funding in FY 1976 coupled with reprogramming efforts in the health program of ERDA permitted initiation and growth of major activities addressing the problems of the non-nuclear energy technologies of ERDA.

Figure 1 describes the ERDA strategy for evaluation of the potential hazard of a large number and variety of potentially hazardous agents to which segments of the occupational and general population might be exposed in the course of development and commercialization of advanced fossil fuel conversion facilities. The following elements are shown and correspond closely to the main health objectives in the Interagency Working Group Report(1) often referred to as the King-Muir Report.

1. Chemical identification of chemical agents present.
2. Bioidentification of presumptive toxic agents.
3. Determination of the dose-effect relations for identified toxic agents.
4. Theoretical and experimental modelling to facilitate extrapolation of animal data to man.
5. Use of experimental information to predict risk estimates for man.

Two research elements are shown that relate to the dose-effect effort, namely, (a) metabolism and fate of toxic agents in experimental animals and in man as tissue samples become available, which relate the local dose to tissues at risk; and (b) development and use of sensitive and early indicators of tissue damage which relates directly to early identification of toxic effects.

CHEMICAL IDENTIFICATION

1. Program Discussion

Major programs are underway at ERDA energy centers to identify and quantitate trace and heavy metals and organic compounds in process streams, products, byproducts, and aqueous and solid residues and effluents of laboratory and pilot plant facilities involved in synthetic fuel production from coal and oil shale. ERDA National Laboratories and Energy Centers collaborate in measurements as well as development of advanced analytical methods and systems. These facilities also provide crude and separated fractions of product and waste for biological testing.

2. Projection

As the bioassay programs expand there will be a need for large-scale preparation and standardization of isolated and purified samples for biological testing. We have projected this need as well as one that involves a development program in analytical chemistry to provide more sensitive and rapid analysis for trace organics and inorganics in tissue residues and body fluids.

BIOIDENTIFICATION OF TOXIC AGENTS

1. Program Discussion

Major programs are underway to perfect and apply rapid *in vitro* and *in vivo* methods to identify carcinogenic and mutagenic agents in coal and oil shale synthetic products, byproducts and residues. *In vitro* systems utilize organisms which range from bacteriophage, through bacteria, to mammalian and human cell transformation systems including *in vivo* transplantation to confirm cell transformation. For mutagenesis screening one large mutagenesis testing laboratory has been set up at Oak Ridge National Laboratory which utilizes a multitier system ranging from bacteria, to Drosophila, mammalian cells to specific locus and somatic cell mutations in mice. In addition, a number of cell systems are being developed using fast-flow fluorometry to detect chromosomal changes and sperm cell morphological changes which may be applied to exposed animal and human populations.

2. Projection

It is important to note that rapid screening systems developed for mutagenesis screening, especially bacterial and bacteriophage systems, are more reliable indicators of carcinogenic activity than for mutagenic activity. Much more effort is required by all agencies to perfect simple rapid screens for the variety or kinds of damage to the genetic material that may be expressed as mutagenesis. ERDA and NIEHS conduct efforts aimed at perfecting systems capable of providing rapid screening for mutagenesis. There is a real need for continuous exchange of information between these agencies and ultimately collaborative interagency efforts to ensure that promising leads are adequately funded.

DOSE-EFFECT RELATIONSHIP FOR PRODUCTION OF MUTAGENIC, CARCINOGENIC, TERATOGENIC, AND PATHOPHYSIOLOGICAL EFFECTS

1. Program Discussion

Major programs have been initiated to obtain information on acute, subacute and latent effects of gaseous and particulate effluents from coal combustion and conversion facilities. Heavy emphasis is placed on aerosol sulfates at one laboratory and particulate-sulfate interactions as well as fly-ash and trace and heavy metals at another. The nature of the pollutants predetermines the primary interest in inhalation problems and production of subacute and latent diseases to the respiratory tract.

At Oak Ridge a large program is in place to evaluate the carcinogenic effect of organic and inorganic chemical agents encountered at all stages of coal liquefaction and gasification facilities. These studies involve the sequential strategy described earlier, namely, rapid *in vitro* and *in vivo* screening, *in vitro* and *in vivo* cell and organ culture and finally long term dose-effect studies on mice and other short-lived rodents.

Most of the efforts carry with them the necessary elements of metabolism and *in vivo* fate to define the tissue dose-effect relationship.

At Oak Ridge National Laboratory, a complete mutagenesis testing unit is also in place which includes dose-effect studies for specific locus and chromosomal mutations in mice. As mentioned previously, the testing unit includes most of the sequential elements in the ERDA health effects plan.

Small programs are underway in several laboratories to evaluate teratogenic potential of heavy metals and hydrocarbons associated with fossil fuel technologies.

2. Projection

Most of the programs described are in their infancy in that the large integrated programs in several laboratories have progressed only to the stage of large-scale screening. As new agents are identified as presumptive carcinogens or mutagens they must be demonstrated to show such activity in the more elaborative, expensive and time consuming animal bioassays. Expansion of these efforts will coincide with the reduction in some of the large-scale studies of the same type previously devoted exclusively to problems in nuclear energy technology.

It is recognized by all agencies involved in evaluation of environmental pollutants that potential synergism exists among mixed pollutants in "real life" exposure of the human population. This type of interaction is not easily evaluated in any of the rapid *in vitro* screening techniques, and thus compounds the time and expense of large-scale animal bioassay. Development of new innovative methods to obtain such information should receive high priority in the interagency plan and a specific interagency task force should address this need.

THEORETICAL AND EXPERIMENTAL MODELLING TO IMPROVE PREDICTION OF HUMAN RISK ESTIMATES

1. Program Discussion

A large part of the ERDA program which presently addresses health problems associated with nuclear energy has progressed to the stage of theoretical and experimental modelling. Much of the emphasis is on prediction of life-shortening and carcinogenicity at very low doses and predictions of risk to man from information obtained with experimental animals.

Likewise, theoretical and experimental modelling for human mutagenesis is a key element in the ERDA program with major emphasis on extrapolation of animal data to man at low doses.

Several programs have been initiated to develop the same type of effort for chemical pollutants. At the present time most of the effort concerns the temporal aspects of tumorigenesis for known hydrocarbon carcinogens, and attempts to define the role of initiation and promotion in tumorigenesis.

2. Projection

Much more effort should be made in both theoretical and experimental modelling not just for carcinogenesis but for mutagenesis and pathophysiological effects as well. Most of the productive efforts are multidisciplinary in that teams of mathematicians and biologists are required. We are beginning to receive proposals from multidisciplinary teams in the National Laboratories and Universities and should project funding of select ones that address health problems relevant to developing energy technologies.

INTERAGENCY PARTICIPATION

A substantial portion of the ERDA non-nuclear health studies program was initiated with interagency supplemental funds. Most of the work initiated is conducted in the national laboratories with about seven percent conducted in universities. About 50 percent of the interagency funds will appear in the ERDA base-budget in FY 1977.

RESOURCE ALLOCATION

ERDA had a small effort in chemical mutagenesis and carcinogenesis for several years prior to the interagency energy supplement. The interagency funding coupled with reprogramming in efforts supported by the base program in FY 1975 augmented the health studies substantially. The total health studies budget devoted to non-nuclear energy technologies is shown below ($\$ \times 10^6$).

FY 1974		FY 1975		FY 1976	
Base	Interagency	Base	Interagency	Base	Interagency
0.8	0	8.0	6.0	17.0	2.6

CONCLUSIONS

The Interagency Working Group Report[1] provided a first step in interagency planning to provide health effects information required for large-scale technological development to accomplish national independence for energy sources in the near and intermediate term.

Within ERDA, with the help of interagency supplemental funds, a large-scale research effort has been initiated which addresses primarily the potential health problems associated with advanced and emerging energy technologies notably those involved in synthetic fuel production from fossil energy resources.

The ERDA plan for evaluation of health impact of new energy technologies and the strategy for implementation of research, while sequential in nature, corresponds in a general way to that proposed in the Interagency Working Group Report[1].

Most of the ERDA effort is made in the national laboratories with emphasis on integrated efforts encompassing several or all of the key objectives set out in the ERDA plan.

The interaction and collaboration of the ERDA National Laboratories and Energy Centers provides an information exchange and a recognition of real-life problems associated with advanced technology.

The ERDA health effects program represents a large effort still in its infancy and will require major expansion if it is to supply the information required by a rapidly developing industry.

There are missing gaps in ERDA's program which must be filled. Likewise there is a great need for "new" experimental and theoretical approaches to accomplish the ultimate goals of the national energy program.

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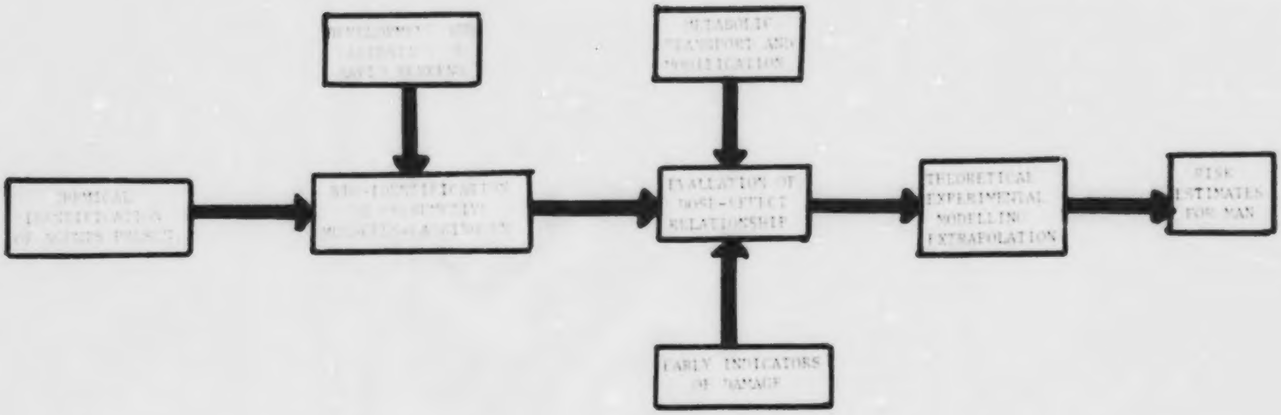
Figure 1. - Research Strategy


DEVELOPMENT AND VALIDATION OF RAPID SCREENS
METABOLIC TRANSPORT AND MODIFICATION
CHEMICAL IDENTIFICATION OF NOXIOUS PRODUCTS
BIO-IDENTIFICATION OF PREDOMINANT MUTAGENS & CARCINOGENS
EVALUATION OF DOSE-EFFECT RELATIONSHIP
THEORETICAL EXPERIMENTAL MODELLING EXTRAPOLATION
RISK ESTIMATES FOR MAN
EARLY INDICATORS OF DAMAGE

DISCUSSIONS TO HEALTH EFFECTS SESSION

Question: What are the health effects on a population in a given region of a single installation? What is the value of such an analysis? Can it be accomplished using a reservoir of 500 people such as a nursing home?

Panel Response: The Environmental Protection Agency plus many other agencies have conducted many extensive population studies from single sources and multiple sources. It is very difficult, however, to dissect the contribution of one source in any metropolitan area from all the other sources. As far as the nursing home population used as an example of susceptible populations, it was pointed out that there is a hazard using a susceptible population whose disease processes are so far advanced that the incremental effects of environmental factors may be masked by the natural processes taking place within the population.

Question: What current or proposed programs are there in the area of extrapolation of data from laboratory experiments to man?

Panel Response: NIH has two programs both related to carcinogenesis, trying to understand the temporal aspects of tumorigenesis and looking at the actual chemical dose to the tissues. The program is also designed to determine whether a chemical agent is acting as an initiator or producer of cancer and otner cell malfunctions.

Question: Are there other programs outside the cancer program that are underway that can be used to extrapolate effects to man?

Panel Response: The Cancer Institute is very active in extrapolation of data. There will be a meeting in March in Pinehurst extrapolating the results of animal studies to man and focusing on carcinogensis and chronic toxicity. In the area of immunization technology, there are several toxicology models available that could pertain to extrapolation to man. Human respiratory diseases are relatable to environmental factors under a variety of circumstances. Potential differences between laboratory animals and man, the different ways various species toxify, detoxify, or metabolize chemicals will greatly influence the abilitv to extrapolate laboratory data from animal studies to effects on man. These processes can also vary within species either due to genetic background differences or the effects of other environmental agents which can modify the basic processes.

Question: How would the panel compare the overall impacts on health and environment from underground mining with strip mining on a national level?

Panel Response: No simple answer can be provided. It is necessary to understand the problems of each mining method and to make every effort to resolve the problems whatever they may be.

Question: Would the panel respond to the general analogy between fuel gasification and petrochemical plants from the viewpoint of hazards to the workers?

Panel Response: Both deal with the emissions of polynuclear aromatics; combining emissions of TNA's perhaps with trace metals plus possibly arsenic and certain sulfur compounds, all of which are very suspicious by themselves no matter what the total of interaction may be. In addition, there is concern about the gasification process being not very well controlled at this stage of development. Accordingly, at this stage, additional studies may be necessary to determine or compare the hazards of emissions of various gasification concepts with those of coal gasification process which has much more data available. The gasification processes at this time project carcinogenic risk to workers and perhaps to general populations surrounding that facility until proven otherwise.

Question: Are there any studies being conducted which compare the total environmental and health impact of one system versus another all the way from extraction to the generation of electricity or steam, such as in the nuclear or coal gasification systems?

Panel Response: A group at Brookhaven National Laboratory is looking at the full cycle of health problems with a variety of different energy alternatives.

Question: In view of the rapidly changing social and legal attitudes towards human experimentation, what are the bans or difficulties that are foreseen in future clinical studies selecting human experimental data that we must have?

Panel Response: No real problem is foreseen -- the attitude and restraints expresssed by society and Congress, is on the balance, quite healthy. The clinical research has been designed and conducted in such a way that they are well within the limits that can be foreseen. Any changes in legislation are not expected to jeopardize any research planned in this area.

Question: What is being done to bring the health effects, environmental effects, and the occupational effects experts into the early stages of engineering decision-making so that effective and meaningful trade-offs can be made and still meet the environmental, health, and cost objectives?

Panel Response: A strenuous conscious effort is necessary to realize the need for such cooperation. Dr. Liverman, the Assistant Administrator for Environment and Safety at ERDA, has principal responsibility for insuring this type of cooperation for ERDA and ERDA interagency projects. Other agencies realize the cooperative effort required and have made similar assignments.

Question: Are there any studies being conducted on secondary effects such as from the bioaccumulation of heavy metals, organics, etc. through the food chains from coal gasification plants, mining operations, and so on?

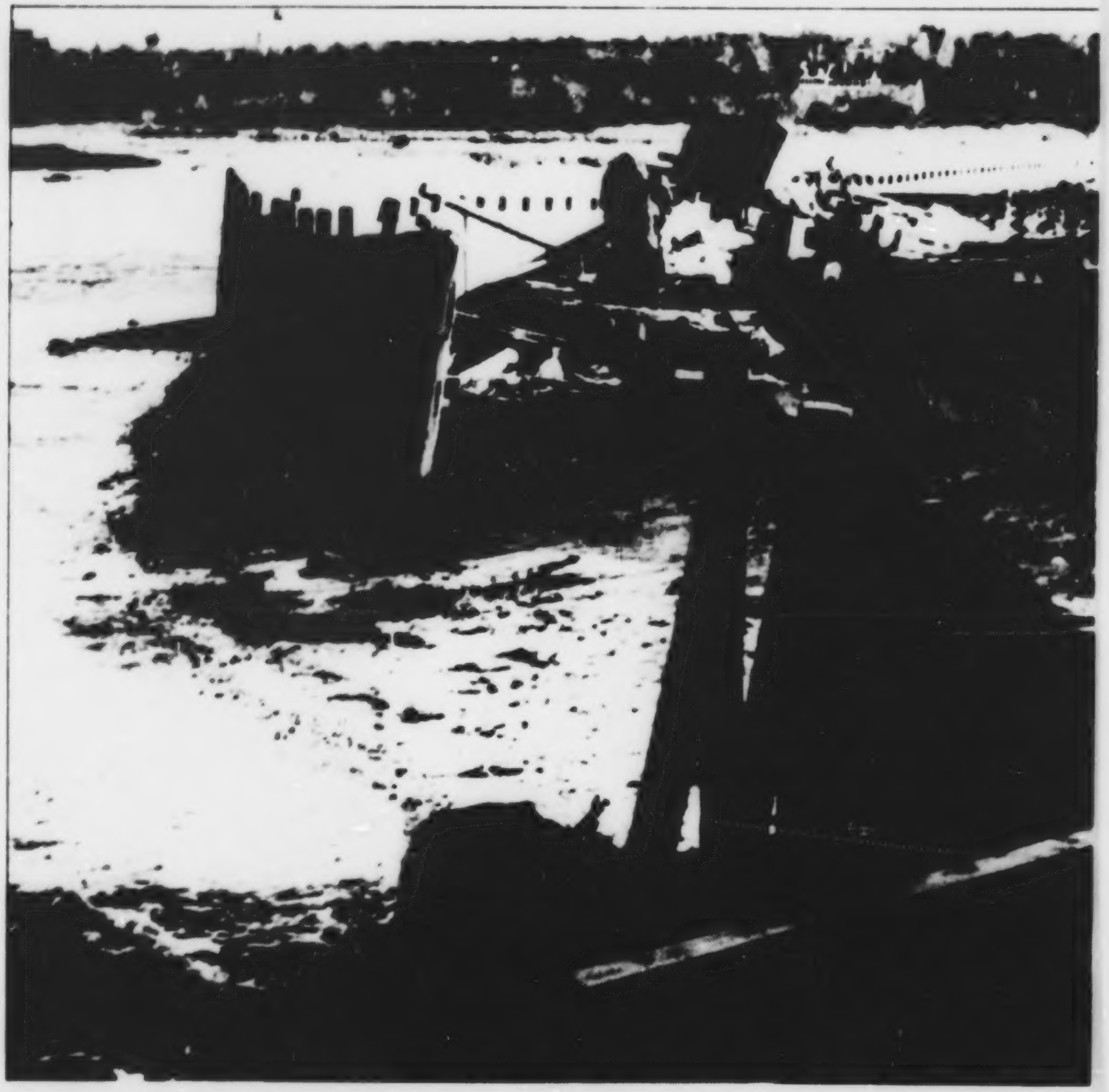
Panel Response: In the past, fresh water and ultimately salt water were the dumps for almost everything. This has ceased to a large extent. Many agencies are now conducting meaningful research in this area. These will be described in subsequent sessions of this conference.

Question: Are the human dose-response relationships for radiation and for fossil fuel, particularly coal, sufficiently well-known at this point to perform a quantitative social balance between these two technologies for the generation of electricity?

Panel Response: The dose-response relationships with respect to radiation are very well-known. The dose-response relationships with respect to constituents emitting from coal are not well defined, albeit there is information available that can be used to make some decisions. It is felt at this time to be far better to try to make an educated guess than to do nothing. As has already been mentioned, there are some concerns involved with polyaromatic hydrocarbons some of which are carcinogenic. Other concerns are the impact of heavy metals on carcinogens. This knowledge can be taken in consideration in the design of subsystems to remove or mitigate the environmental impact of these two pollutants.

CHAPTER 5

MARINE ECOLOGICAL EFFECTS



INTRODUCTION

The narrow coastal zone fringing the continents, and the surface layer of the sea, to only a few meters in depth, comprises less than one percent of the volume of the oceans. Yet this area, comprises more than 90 percent of the seas primary productivity and living biomass. These land-water-air interfaces are also sites of disproportionately high human activity.

Our ability to alter the environment continues to increase at a rate that far exceeds our ability to predict the environmental consequences of our actions. As the nation seeks to develop its energy resources, this capacity for environmental alteration will impact heavily on this sensitive coastal portion of the marine environment.

Environmental alteration of the marine environment results from materials intentionally dumped or spilled in the oceans, runoff of pollutants from rivers and streams, and emissions from facilities located on or close to the coastline.

Heavy metals and petroleum hydrocarbons are pollutants known to be entering the marine ecosystem and known to adversely effect marine organisms.

Spectacular oil spills result in less than two percent of the global input of petroleum hydrocarbons to the oceans. The major source of this and other pollutants entering marine waters results from routine transport of energy related emissions. Additionally, generation of electric power in coastal regions will affect the marine environment through regional increase in water temperatures in proximity to the plants, and entrainment and destruction of marine organisms.

A case can be made that all environmental changes are not necessarily harmful, nor are all changes caused by human activities. Natural changes in coastal water temperatures have resulted in corresponding changes to the local marine ecosystem. Whether such a change is harmful may be a matter of opinion. However, it remains that materials are being released to the marine environment which are persistent and toxic to marine life. Our lack of ability to accurately predict the effect of these pollutants, leaves the question of whether the natural functions of the oceans themselves might be in jeopardy.

Ecological efforts of several agencies in this field are concerned with the development of ecological information, impact assessment, and basic research through a series of in depth studies of selected oceanic areas.

AN OVERVIEW OF ENVIRONMENTAL EFFECTS

by

Dr. James L. Liverman

Assistant Administrator for Environment and Safety
U.S. Energy Research and Development Administration

Washington, D.C.

It is over two years since the Arab oil embargo and the urgency of an energy shortage may be overshadowed by our celebration of the Bicentennial Yet as people "rediscover" America, it may be difficult to reconcile Jefferson's vision of a "pastoral paradise" with the realities of today's industrial society. Since 1776 we have built a nation and created a life style based on seemingly unlimited resources of land, minerals, and energy, with little concern for resource allocation or environmental effects. Now the days of a plentiful energy supply are gone and we have a grossly insulted environment which can't stand much more abuse.

We have come to recognize that energy at the expense of the environment is no bargain or vice versa. Unless we are willing to accept radical changes, a balance must be achieved between our need for energy and our concern for the environment. ERDA was created to provide the needed new technology options which will permit us to meet the Nation's technology needs in an environmentally acceptable manner. Society's decision regarding the acceptability of an energy technology will depend largely upon the availability of environmental, health, and socioeconomic data as well as the status of environmental control technology. And the options chosen in 1976 may well have as much impact on our future as did our decisions of 1776.

I don't need to tell you that we haven't always been this cautious in the environmental area. It is because of our previous short sightedness that we are now discovering and coping with our earlier haphazard approach to energy development and use. Even though none of us are completely green in this area, take almost any non-nuclear energy process, and our knowledge of its pollutants and their effects is limited. In addition, the complexity of a pollutant's interaction with ecological systems in the environment, its chemical alterations and hazardous effects, have yet to be determined. Not enough attention has been paid to these kinds of problems in the past, and we are just now determining the magnitude of their impact.

The National Plan which ERDA presented to Congress last year (and which is undergoing revision for 1977) recognizes a number of energy technological options which are being developed for the short, mid, and long term, including coal gasification, liquefaction, extraction, and combustion; oil shale; geothermal; solar; and nuclear fission and fusion. A strong integrated technology program, coupled with an equally strong environmental overview and assessment program, is essential to ensure that all these options are constantly surveyed for potential environmental and health impacts and that the right questions are being asked from the start. We can't afford any surprises in this area nor can we afford any delays.

Unfortunately, however, the environment recognizes no neat energy insult categories. Whether a pollutant comes from the burning of coal for electric generation or from the steel-making process, its effect will be equally devastating to the environment. Congress and the OMB recognized long before the creation of ERDA that solutions to energy-related environmental concerns could not come from one federal agency alone. No one agency can effectively harness all the talent and resources needed to get the job done. Instead, by interacting with one another, by agreeing on joint projects, and by pooling resources, each concerned agency can lend its unique talents, perspective and ongoing efforts to the goal of providing adequate, safe, clean energy to the Nation.

Let me mention only a few of the issues we must address collectively: Obviously, we need to pursue those technologies which will permit an immediate major expansion of existing energy resources, such as direct use of coal by utilities, nuclear converter reactors and enhanced recovery of oil and gas. At the same time, we need to emphasize conservation in all aspects of our daily life - in buildings, industry, transportation efficiency, consumer products, and waste conversion techniques.

While all these alternatives are in place at the present time, there are many potential long term and cumulative environmental and health effects which we must continue to evaluate, as well as new methods to control pollutants and waste problems.

In the fossil fuels program, for example, our health studies must address such areas as epidemiological studies on coal conversion plant workers; screening for mutagenic, carcinogenic, and embryotoxic effects; quantitative assessment of dose-effect relationships following exposure to fossil related effluents; and toxicity relationships of trace elements in the various stages of mammalian development, to name only a few.

Our biological programs must further address the problems associated with inhalation, such as research on lung cells in culture, the pollutant-induced changes in lipoproteins and enzymes of lipid metabolism in lung membranes, and the reaction of free radicals of polycyclic hydrocarbons with nucleic acids.

These programs must be supplemented by research in the environmental areas so that we will know how fossil-related effluents are transported and interact within ecological systems on land, in the atmosphere, and in aquatic systems, as well as the major pathways of transfer and the rates of occurrence. The MAP3S (Multistate Atmospheric Power Production Pollution Study) is one program through which EPA, NOAA, and ERDA are obtaining valuable information on the effects of airborne coal combustion contamination in the atmosphere. In addition, we need to collectively address the problems associated with acid mine drainage and stream transport of toxic substances; land reclamation, including revegetation, soil/plant/nutrient relationships, and wildlife habitats. With increased offshore drilling, we must determine the toxicological effects of crude oil and other petroleum derivatives on marine biota.

Finally, we must develop models to aid us in predicting various phenomena such as the mechanisms of ionic clustering and particulate accretion, or the characterization of pollutants in mine drainage or solid waste runoff. Then we must perform analysis and assessment studies to determine the impacts of these technologies on a regional, state and local level in order to make cost/risk benefit or tradeoff analyses; for instance, the impact of an accident on an ecosystem and the resulting social consequences.

But for all our research, we must keep in mind that neither ERDA alone nor any other federal agency can assure the development and commercialization of environmentally acceptable energy systems. Environmental acceptability represents a societal judgment based on the perceived benefits and detriments of the energy systems implementation.

Clearly, another area of environmental concern must be how to bring the information we gain to the people, regional, state, and local, who will have to live in proximity with the newly commercialized technologies and extraction processes. In many cases, we are talking about areas of the country that have known little previous development. The environmental, aesthetic, ecological, social, cultural, and economic impacts must be completely, accurately and objectively assessed--and people must be made aware from the start of the costs of accepting or rejecting the benefits/costs of energy production. That is why we must pay increased attention to the assessments of regional impacts of an energy technology.

ERDA is conducting a regional studies program, designed to predict and evaluate the socioeconomic, human health, and environmental and institutional impacts related to the development of all on-line and prospective energy sources. Six ERDA labs are coordinating the program on a regional basis and have direct contact with state governments. While this program is designed to provide information to ERDA on potential environmental problems, it is also designed to provide "feedback" to the states for use in energy policy decision making.

Endeavors of this nature are particularly important because there are few simple solutions or technological "quick-fixes" in the ecological world. To ensure that permanent and long lasting ecological damage does not occur, we must further assess the effects of our actions on the ecosystems themselves. Which leads me to believe that we must give additional attention to development of actual outdoor laboratories where the impacts and interactions of pollutants and the resulting effects may be monitored. As you know, ERDA has two National Environmental Research Parks in place, Savannah River and Idaho, which are designed to fill just this function. We have proposed additional sites for designation: Los Alamos, Oak Ridge, Hanford, and the Nevada test site. The establishment of a network of NERP's is a logical outgrowth of the environmental goals and requirements stated in the National Environmental Policy Act (NEPA), the Energy Reorganization Act (ERA), and the Non-Nuclear Energy Research and Development Act (NNERDA).

These NERP's would provide us with the capability to: (1) develop methods to quantify and continuously assess and monitor environmental impacts from man's activities, (2) develop methods to estimate or predict environmental response to proposed and ongoing activities, and (3) demonstrate the impact of the various activities on the environment and evaluate methods to minimize adverse impacts. But even more importantly, each NERP could be used by the entire federal sector to determine needed ecological information which in turn could be used to provide the public with an assessment of the environment and land use options open to them. These would provide another coordinating mechanism whereby the unique capabilities of each concerned agency could be brought to bear on the problems, arriving at workable solutions.

There are just a few of the things that we should consider as we continue our research for the answers to energy-related environmental and ecological problems. Nowhere is an overview more important. We must work closely and cooperatively and share our different perspectives if we are to provide the "answers" to the technology questions being raised.

At present, our need for energy alternatives is great; their development essential; their impact on our environment in many ways uncertain. Yet concern for the environment will not be sacrificed in our haste to bring alternative technologies into use. Future decisions will be made in the larger context of our continuing effort to improve the quality of life. The definition of "improvement" may depend quite a bit on what we know about the health, environmental and safety aspects of our energy alternatives. If we haven't taken the steps necessary to integrate the concerns for preservation, enhancement and protection of the environment within our energy options, we will most likely have lost our ability to choose. ERDA's environment and safety program is designed to ensure that this does not happen. But, it is not our job to do alone. We must work closely and cooperatively not only with the technologies and with each other but also with regional, state and local governments, industry and the public to achieve our goals. Working together, the decisions won't always be easy not our interactions always smooth; but out of our efforts we will create a stronger, more viable energy base for the Nation.

ASSESSING IMPACTS OF ENERGY DEVELOPMENT ON COASTAL FISH AND WILDLIFE RESOURCES

A.W. Palmisano
Office of Biological Services
U.S. Fish and Wildlife Service
Washington, D.C.

INTRODUCTION

The narrow coastal zone fringing the continents and the surface layer of the sea, to only a few meters in depth, comprises less than one percent of the volume of the oceans yet represents more than 90 percent of the seas primary productivity and living biomass. These land-water-air interfaces are also sites of disproportionately high human development activities. Though coastal areas have been used for centuries by man for transportation, food production and habitation, only since the turn of the century has our technology developed to the point where major ecosystems and possibly the natural functions of the oceans themselves might be jeopardized. This poses a significant problem to those of us trying to plan for a future with both a high standard of living and a high quality of life. Our ability to alter the environment continues to increase at a rate that far exceeds our ability to predict the environmental consequences of our actions. The present energy dilemma which we face will almost certainly broaden this range of relative ignorance. Impact assessment state-of-the-art relative to coastal and marine systems has not developed beyond an approach which involves avoiding the actual or potential "big bads".

FISH AND WILDLIFE SERVICE RESPONSIBILITIES AND ACTIVITIES

Historically the FWS has performed a number of functions for the administration. The first half of this century saw the Biological Survey undertake basic life history studies of many forms of wildlife both game and non-game. The emphasis gradually changed to land management for wildlife which involved acquisition of refuges and activities to enhance the production of wildlife on both public and private lands. By mid-century the Service had become primarily a management agency, managing its own refuge lands, and through hunting regulations, the nations vast waterfowl population. A considerable ecological capability was housed in the Service which, when, in the sixties, the public acquired an environmental consciousness, could assist decision-makers in developments requiring environmental impacts. The role of the Service as an ecological advisor has steadily increased since that time.

Presently the FWS has management responsibilities for migratory birds, endangered species, selected marine mammals, anadromous fishes and national wildlife refuges. In its advisory role, the Service reviews and comments on environmental impact statements and many permits requiring appropriate federal participation. The agency also provides technical assistance in activities involving comprehensive natural resource planning at national, regional, state and local levels.

The Office of Biological Services has recently been established to improve FWS advisory capabilities by: 1) development of appropriate ecological information; 2) improved impact assessment; 3) development of information transfer mechanisms to bring information effectively to bear on decision-making processes.

DEVELOPMENT OF ECOLOGICAL INFORMATION

The varied nature of the disturbances and the diversity of resources subject to impact require a broad base of information to adequately assess development impacts in the coastal zone. The approach being developed by the Service to develop this base involves a comprehensive characterization of coastal ecosystems. Environmental Characterization may be briefly defined as a structured approach to ecological information development, synthesis and analysis designed to provide an understanding of the functional processes and natural resource elements comprising complex coastal ecosystems. The procedure makes maximum use of existing information essential to the resource assessment and in providing guidance to the development of future studies. A description of significant natural resources and functional process of the ecosystem are highlighted in the characterization. EPA pass-through energy R & D funds are being used to develop the approach to environmental characterization.

In addition to characterization, special studies are conducted to monitor environmental changes attributable to development. Ecological indicators are evaluated and selected as representative of some aspect of the ecosystem. An example is the bioaccumulation of environmental contaminants in animal tissues representing various trophic levels or change in community structure indicating increasing salinities resulting from alternation of fresh water flows.

IMPACT ASSESSMENT

The Service provides technical assistance to other federal agencies in the preparation and review of EIS and the issuance of permits for development activities in the coastal zone. Improved impact assessment capabilities is a primary objective of the Office of Biological Services.

Analysis of industry activities related to OCS development is presently being undertaken to determine the nature of the environmental disturbances to be anticipated and an evaluation of optional approaches. All phases of development must be considered and a comprehensive environmental studies program designed to provide timely planning information for each step of development. Environmental studies should be scheduled to provide essential resource information early in the leasing program to determine tracts which should be excluded from the sale and to establish appropriate lease stipulations. Exploratory drilling requires permits and often detailed ecological information near the platform site. Production and transportation of petroleum initiates a series of development activities often removed from the lease area. Pipelines, navigation dredging, chronic and acute spills, near and onshore development of storage and service facilities are only a part of the total environmental impact of production and the coastal zone will undoubtedly feel the brunt of these impacts.

Information provided by the environmental characterization will identify the distribution of the significant living resources as well as essential and unique habitats. Extensive permanent alteration of these resources should be considered a "big bad" to be avoided in the course of normal development. Other living resources are addressed in the impact analysis but are considered more "expendable" than the significant resources and do not necessarily dominate the decision process.

In addition to living resources, processes which drive the coastal ecosystems are also subject to alteration by development. Living resources are part of the web of life and significant disruption of processes such as nutrient cycling, hydrologic patterns, successional trends and trophic relationships can have a severe detrimental impact. The state-of-the-art is generally inadequate for predicting such changes but the potential threat is no less real. Studies designed to improve predictive modeling of major coastal ecosystems will probably occupy the time of investigators for many years to come before adequate models can be developed which quantitatively predict impacts.

The Service's approach makes maximum use of the state-of-the-art relative to impact analysis. To make full use of presently available technology, four separate lines of investigation are being persued: 1) Literature Review; 2) Case history studies; 3) Consultation with acknowledged experts in the respective fields; 4) An analysis of the permit process within the FWS.

In addition to maximizing available information on impact effects, a major effort has been undertaken with EPA pass-through funds to assess the toxicological and physiological effects of hydrocarbons on coastal water birds. Initial experiments will subject wild strains of mallards to low level concentrations of petroleum compounds to determine toxicological and physiological effects and to further develop appropriate analytical procedures. In subsequent studies, experiments will be performed on seabirds to determine deviations from results experienced in the laboratory.

The volume of environmental information presently being developed staggers the imagination. Sophisticated information transfer mechanisms are required to make full use of even a fraction of the data available. The Service is developing an information transfer network designed to provide maximum use of systems currently in use and to store and retrieve information being developed by ongoing studies. Development decisions and comprehensive planning efforts are underway and decisions are being made now. The best decisions will be made in light of the best information available.

NOAA RESEARCH ON MARINE ENVIRONMENTAL EFFECTS OF ENERGY-RELATED ACTIVITIES

James B. Rucker
National Oceanic and Atmospheric Administration
Rockville, Maryland

INTRODUCTION

As this nation seeks to develop more fully its energy resources it is clear that energy-related activities will affect the marine environment. Based on the premise that expansion in selected areas of environmental research and development is needed to cope with environmental impacts that may result from an acceleration in developing energy resources, NOAA submitted eleven proposals for environmental/energy research to EPA for energy-related pass-through funding. This past summer a NOAA-EPA Interagency Energy Accomplishment Plan was finalized and funding was made available to implement the program. Three of the eleven research and development projects deal with the effects of selected energy-related activities on the marine environment. These projects and names of the project managers are:

- An Environmental Assessment of Northern Puget Sound and the Strait of Juan de Fuca - Dr. Howard S. Harris, NOAA-ERL, Seattle, Washington
- An Environmental Assessment of an Active Oil Field in the Northwestern Gulf of Mexico - Dr. Joseph W. Angelovic, NOAA-NMFS, Galveston, Texas
- Fate and Effects of Toxic Metals and Petroleum Hydrocarbons on Selected Ecosystems and Organisms - Dr. Douglas A. Wolfe, NOAA-ERL, Boulder, Colorado

The purpose of this paper is to describe the approach and progress of these three projects. The other NOAA energy-related projects deal principally with atmospheric effects, and measurement and monitoring. These projects are being addressed separately in these proceedings.

The three NOAA projects were all new initiatives and the first step in implementing these projects was to expand the Interagency Energy Accomplishment Plan into a complete five-year project development plan. Project managers were assigned the responsibility of drafting the detailed plans. All three projects are of an interdisciplinary nature, and all involve tasks that must be accomplished by a number of NOAA mainline components. Therefore, a technical task team was assembled to review and critique the draft project development plans. NOAA components that are involved with implementing significant portions of the research were represented on the technical task team. The components included:

- National Marine Fisheries Service
- National Ocean Survey
- Environmental Research Laboratories
- Environmental Data Service
- Office of Sea Grant

Draft project development plans were submitted to the technical task team in August, and in early September project managers met with the technical task team to finalize the project development plans. The effective date for actually initiating the projects was September 1975.

ENVIRONMENTAL ASSESSMENT OF NORTHERN PUGET SOUND AND THE STRAIT OF JUAN DE FUCA

This project is designed to develop ecological data needed for assessing the potential impact of petroleum hydrocarbons on the ecosystem. The results of this research will be immediately applicable to regional management and development decisions on the location of deepwater ports, expansion of refinery capacity at existing sites versus the development of new sites, and the regulation of tanker traffic in parts of the Sound.

Petroleum Related Activities

The petroleum industry within the Puget Sound region has generally experienced growth commensurate with the region's population and industrial growth. Recently, however, the amount of tanker traffic through the Strait of Juan de Fuca has increased, and a further intensification of petroleum transport and refining activities is anticipated during the next few years. There are several factors which account for this expansion. Until recently much of the oil requirement of the Pacific Northwest has been supplied by Canadian crude oil delivered to U.S. refineries via pipeline. This flow now has been substantially reduced, and Canada plans total phaseout in the early 1980's. Not only has this required additional tanker traffic to make up the U.S. deficit, but also it results in a surplus of crude oil in western Canada which is shipped out from terminals near Vancouver through the Strait.

Because of its proximity to the termination of the Trans-Alaska pipeline, some thought has been given to making the Puget Sound region a transshipment point for other marketing areas. The Oceanographic Commission of Washington, in a study done for the state legislature, has evaluated several scenarios of this type, and it estimates that Puget Sound refinery capacity could double by 1980 and that tanker transport of crude oil could be increased by as much as tenfold by the turn of the century.

The waters of the greater Puget Sound region, with few exceptions, have not been subjected to massive oil spills or the environmental problems associated with continued release of small amounts of oil, despite a long history of petroleum transport and refining. However, with the dramatic increase in tanker traffic and refinery activity that has been predicted for the next decades, a catastrophic spill or the realization of serious biological effects due to chronic low-level emissions cannot be discounted. It is the aim of this EPA-funded energy-related research project to develop an understanding of the ecology of the system and to provide environmental data needed to assess the potential impact of petroleum-related activities on the ecosystem.

Project Design

The project research is organized into four major tasks. The first of these is to characterize the major marine biological populations subject to impact by pollution resulting from petroleum transportation and refining. The second task is to determine the existing distribution and concentration of pollutants within the ecosystem which are associated with refinery effluent and petroleum. A third task is to characterize the principal processes and major pathways by which petroleum moves through the marine ecosystem. The final task is to provide decision-makers with environmental and ecological information and predictions of the effects of oil-related activities upon the ecosystem.

Project Progress

A data management system was developed and initiated in December 1975 to provide storage and retrieval for project data as well as bibliographic support for project investigators. This effort is being conducted by the NOAA Environmental Data Service. Acquisition of principal existing data sets on the region has been accomplished. An assessment of the existing meteorological network covering the study region, and recommendations for upgrading the network to support the project has been completed by the project office. An upgraded meteorological network is scheduled to support project oceanographic studies for February 1976.

Proposals for investigating the intertidal communities and water circulation and mixing of the region are being evaluated. And a proposal for investigation of plankton distribution is under review. These investigations are scheduled to begin this winter.

AN ENVIRONMENTAL ASSESSMENT OF AN ACTIVE OIL FIELD IN THE NORTHWESTERN GULF OF MEXICO

The goal of this five-year project is to develop an environmental assessment of an active oil field in the northwestern Gulf of Mexico and to compare conditions that have developed in the established oil and gas field to those in a similar but unaltered area. The objectives are twofold: (1) describe the existing ecosystems and the variability in their major components, both in time and space, for an active oil field and an unaltered area; and (2) compare the concentrations of pollutants in the water, in the sediments, and in the biota, found in an active oil field with those of an unaltered area and identify those changes attributable to oil exploration and production.

Buccaneer Oil Field

The area selected for study is the operational Buccaneer Oil Field located approximately 32 miles southeast of Galveston, Texas. Its proximity to the NMFS Gulf Coastal Fisheries Center in Galveston, Texas, simplifies logistics and reduces the cost of the research. This field has been in production for about 15 years, which has allowed time for full development of the oil field-associated climax marine communities. Its isolation from other fields facilitates the selection of an unaltered area for comparison near or adjacent to the field.

The Buccaneer Oil Field was developed by the Shell Oil Company in four lease blocks during the years 1960 through 1968. The total area leased is 14,670 acres or approximately 23 square miles. During the development of the field, 18 platforms have been built; two are major platforms, two are auxiliary platforms, and 14 are satellite platforms. Initial exploratory drilling began about mid-summer of 1960 with mobile drilling rigs. Following exploratory drilling permanent type drilling platforms were established. All subsequent drilling and production activities have been conducted from these platforms.

There has been no history of reported oil spills from this field. Although there undoubtedly have been minor losses due to failure of equipment or human error, there have been no major spills.

Project Design

Project activities have been organized into five tasks. The first task is to develop a data base to identify information deficiencies and to provide bibliographic support to the various researchers involved in the study. The second task is to establish a data management system to provide availability and exchange of project-generated data among individuals working in the several research disciplines. The third task is to identify the biological, chemical, and physical alterations in the ecosystem attributable to oil field development. This task is quite comprehensive and includes surveys to investigate the hydrography, water characteristics, sediments, pollutants, and the abundance, distribution, diversity and habitat of major planktonic, benthic, and pelagic communities. A separate survey will be conducted to define the effects of the platforms on the local ecosystem, including community composition and aggregation of species. The fourth task is to determine the presence of selected heavy metal and hydrocarbon pollutants and identify pathways and effects on the various components of the ecosystem. Lastly, a major task will be to develop the capability of predicting the impact of oil field development on the ecosystem and applicability of extrapolation to other areas along the continental shelf.

Project Progress

A pilot study was initiated in November 1975 to determine whether or not the Buccaneer Oil Field is in fact a suitable study site, to obtain preliminary physical and biological data, and to establish a statistically valid sampling distribution and frequency. The pilot study will be concluded in late February 1976. However, interim results suggest that the Buccaneer Oil Field will be a suitable study area. These results also suggest that there is a pronounced decrease in the macrofaunal population in the vicinity of the two major platforms and a concomitant increase in the meiofaunal population.

A request for proposal was developed and issued in late December 1975 to solicit potential university contractors for work on seven work units dealing with sedimentology, benthic fauna, effects of structures, hydrocarbon levels, heavy metals, total organics and hydrodynamic modeling. Work on these topics will begin in late February 1976. Similarly within NOAA, work will begin on bibliographic and data mangement activities by the Environmental Data Service and the National Marine Fisheries Service Fisheries Engineering Laboratory. Investigations on current, temperature and salinity regimes, demersal fishes, macrocrustaceans, pelagic and reef fish and plankton will be initiated in late February 1976 by the National Marine Fisheries Service.

FATE AND EFFECT OF PETROLEUM HYDROCARBONS AND SELECTED TOXIC METALS ON SELECTED MARINE ECOSYSTEMS AND ORGANISMS

Heavy metals and petroleum hydrocarbons are known to affect adversely marine organisms, through both short-term acute or long-term chronic exposure levels. Both heavy metals and petroleum hydrocarbons are concentrated or released by energy development activities. This project is designed to provide laboratory and field investigations of the effects of these pollutants on marine organisms and the ecosystem. Emphasis is placed on subarctic environs.

Project Design

The overall approach of this project is to study specific processes controlling the effects, both physiological and ecological, of petroleum hydrocarbons and selected toxic metals in subarctic marine ecosystems to facilitate the assessment of the impacts of pollutant releases in this ecosystem type. The project includes four interdependent tasks which are coordinated with the other NOAA energy-related projects in Northern Puget Sound and the Gulf of Mexico, as well as the Alaskan Outer Continental Shelf (OCS) Program, and the Marine Ecosystems Analysis (MESA) Program.

The first of the four tasks is to establish a national analytical capability for petroleum hydrocarbons and toxic metals in the marine environment for the purpose of standardizing analytical techniques, providing intercalibration services and conducting routine analysis. The second task is to identify information gaps in our understanding of impacts of subarctic marine ecosystems, and to design a comprehensive program of laboratory and field research to fill those gaps. The third task is to conduct selected laboratory experiments on fate and effects of metals and hydrocarbons. Finally, there is the task of conducting controlled experimental ecosystem research to determine changes at the ecosystem level and to test our ability to predict ecological and biological impacts in subarctic ecosystems. These experiments will be initiated during the third year of the project and be located in the coastal portion of the Northeastern Gulf of Alaska, at a yet unspecified study site.

Project Progress

Funds have been committed for establishing the NOAA analytical facility at the NMFS Northwest Fisheries Center in Seattle, Washington. Procurement of equipment and recruitment of personnel are in progress. It is expected that the facility will be fully established by July 1976.

Planning is underway for a symposium and workshop on the adequacy of research to date as a basis for reliable prediction of consequences of contamination of subarctic marine environs. A provisional date for this workshop has been set for November 1976. The results of the workshop will be most important in developing direction for further experimental subarctic ecosystem research.

Two laboratory research experiments have been initiated. One is to study the effects of petroleum hydrocarbon exposure on bioaccumulation and toxicity of methyl mercury and of chlorinated hydrocarbon residues in selected fish and shellfish. This research was initiated in December 1975 and is being conducted by NOAA researchers at the NMFS Northwest Fisheries Center in Seattle, Washington. The other experiment in progress is to determine the effects of petroleum hydrocarbons on equilibria of toxic metals across marine sediment - water interfaces. This research was initiated in November 1975 and is being conducted by researchers at the NOAA Environmental Research Laboratories in Boulder, Colorado.

SUMMARY

The projects described in this paper constitute the NOAA research effort on the marine environmental effects of energy-related activities. First-year funding provided wholly by EPA interagency funds is 2.17 million dollars. Second-year funding will be approximately 2.10 million dollars. Planned funding for the third, fourth and fifth years is 2.1, 1.9 and 1.7 million dollars, respectively.

Although the projects are only in their beginning stages, schedules are being met and significant progress is being made by researchers in several NOAA components and from contract agencies and institutions.

PARTICIPATION OF ERDA IN THE TRANSPORT AND ECOLOGICAL EFFECTS CATEGORIES OF THE PASS-THROUGH PROGRAM

R. E. Franklin, D. S. Ballantine, J. O. Blanton,
D. H. Hamilton and C. M. White

U. S. Energy Research and Development
Administration
Washington, D. C. 20545

INTRODUCTION

Approximately $4 million was made available to ERDA through the pass-through program late in FY 1975 for environmental research. These funds were associated with a variety of tasks, objectives, subcategories, and categories in the working group report. They were reorganized by ERDA for implementation and management into six major program areas to focus on specific problems and to group-related tasks regardless of the original category. These six program areas and the allocation of funds with respect to the interagency categories are shown in Table 1. These programs are managed and administered within ERDA by the Environmental Program staff of the Division of Biomedical and Environmental Research.

Several points listed below should be understood to appreciate the interagency program.

1) The report of the working group is in no sense a comprehensive plan. It is a collection of tasks which if successfully completed would contribute to a better appreciation of environmental impacts.

2) There was no evaluation of existing base programs by the working group.

3) Nuclear, geothermal, and solar technologies were excluded from consideration on the basis that the NSF and the AEC were already receiving adequate or a "fair share" of funds to deal with the problems associated with these technologies. The only exception to this was a minor amount of funds originally allocated to the AEC for some physical and chemical oceanography related to offshore power plants. Oil shale was almost completely eliminated from consideration largely due to the limited funds which were available, and the expected contribution of that technology in the near-term.

4) The objectives used to classify the research tasks are general and do not group the tasks according to common technological problems or practical research objectives.

5) The tasks are so broad and so ambitious, in most cases, that only through merging the efforts with on-going programs and through sustained effort will the objectives be realized.

The major impact of the pass-through funds has been to permit implementation of research plans sooner than would otherwise have been possible. This was particularly important in the case of ERDA since the Energy Reorganization Act was implemented midway in the fiscal year, and the environmental budget was grossly inadequate to provide for the research needs of the vast array of technological responsibilities given to the Agency.

The Environmental Programs within ERDA include, in principle, the scope of two of the interagency categories, Transport and Ecological Effects, and a portion of the characterization, measuring and monitoring category (CMM). However, for purposes of dealing with pass-through funds the CMM category is managed by the Physical and Technological Programs within ERDA. The Environmental Program budget for FY 1976 was approximately $39 million. As indicated in Table 2, about one-half of that was in support of research directly related to one or more of the six program areas associated with the pass-through funds.

In most cases the pass-through funds provide a modest but useful supplement to ERDA's on-going effort in these areas. In the case of land reclamation and the Alaskan oil program, the supplemental funds are a significant complement.

The major items in the remaining portion of the ERDA budget, (cf. Table 2) which are related to the transport and effects categories, are as follows:

Nuclear Fuel Cycles, Excluding Offshore Power	$7.9 Million
Geothermal Power	0.8 Million
Fundamental Support In Applied Science	4.0 Million
Operational Programs	6.5 Million

The applied science includes research in meteorology and other atmospheric sciences, terrestrial ecology, limnology, oceanography, soil science, etc. The operational programs include such things as support to National Environmental Research Parks, military programs, laboratory site management, and the upper atmospheric program.

Finally, we should recognize that any attempt to orchestrate the total national effort which is related to the environmental and health effects of all fuel cycles would probably be futile. However, we can accomplish a great deal by working to increase the awareness, both at the Agency and the individual investigator level, of the true national effort at the program- and problem-area levels.

The remaining text will describe the new ERDA projects in the six program areas.

LAND RECLAMATION

Nine tasks for which ERDA has responsibility as outlined in the interagency report deal with surface mine reclamation and related problems. With the exception of one task that is specially tailored to oil shale extraction, these tasks relate to coal extraction and utilization at mine-mouth plants. The major research efforts involve a diversified program conducted by the Land Reclamation Laboratory at Argonne National Laboratory (ANL), and the Ames Laboratory, Iowa State University. The Ames study is a cooperative venture with the University of Montana, Montana State University, and the Pacific Northwest Laboratory. Study sites are located in the Southwestern, Northern Great Plains, and Central coal resource regions. The program is built around a series of mine and mine-related sites. The scope and direction of the program can best be understood through the description of the study sites, which follow.

1. Northern Great Plains

There are four study areas in the Northern Great Plains coal region which are related to this program. They range from the lignite fields in North Dakota to the Green River Formation in Southeastern Wyoming.

1.1. Colstrip Site

The objective of the Ames project (Gordon and O'Toole) is to evaluate the significance of changes in trace element concentrations in the grassland system surrounding Colstrip, Montana, as a result of mining operations and coal utilization in the area. Initial efforts have been to determine indigenous levels of trace metals and other potential contaminants in vegetation and wildlife of the area. The goal is to provide biological transfer rates and potential effects data which can be used in the assessment of the ecological impact due to development of the region. Naturally, this study is expected to provide only a portion of the input for such an assessment.

About two-thirds of the financial support for this project comes from the trace contaminants program.

1.2. Jim Bridger Mine Site

This study area is located in the Green River region near Rock Springs, Wyoming. The project is a cooperative effort between the Operator, Pacific Power, and Idaho Energy Resource Company, and ANL (Carter and Cameron). The complex includes a mine-mouth power plant producing 1000 Mwe. This site is particularly important because it represents a region which may undergo considerable development in the future. Low rainfall (6-8" annually), short growing season (42-82 days), and harsh terrain characterize the region.

The primary objectives of this project are focused on efficiency of utilization of available water through improved infiltration and water harvesting techniques. The first series of experiments includes the use of mulches, ground surface manipulations and snow fences on test plots to capture and retain the maximum amount of precipitation.

1.3. Indian Head Mine Site

This study area is located in Mercer County, North Dakota. The mine has been in operation since 1922. Production of lignite has been about one million tons/year since 1967. Prior to 1967, annual production was about 0.2 million tons/year. The main environmental problems at this site are associated with the salinity and high clay content of the overburden, leading to difficulties in establishment of vegetation on reclaimed areas.

The research includes salinity, drought tolerance, and root morphological studies on species which can be used for revegetation efforts; soil placement, segregation, and handling studies with the emphasis on mobilization of toxic elements by soil microflora; and soil chemical and physical modification, particularly as related to nitrogen and sulfur cyclic processes in stored topsoil.

Research on soil microbiology is conducted by ANL staff (Carter and Cameron) in cooperation with scientists from Arizona State University and New Mexico State University.

1.4. Big Horn Mine Site

This study area is situated in the Powder River Basin near Sheridan, Wyoming. The research is conducted as part of the ANL program (Carter and Cameron) in cooperation with the mine operator, Peter Kiewit and Sons Mining Company. The impacted area is traversed by Goose Creek and the Tongue River, which makes it particularly useful for evaluating water quality, sediment transport, and overall aquatic ecosystem effects related to mining. Furthermore, the mine has been in operation about 20 years, a time sufficient to permit significant assessment relative to the accumulation of effects and impacts. The challenge will be to interpret the current characteristics of the site, and interpret other observations in terms of the so-called "undisturbed" state. The experimental design will permit this type of assessment to be made.

The overall objectives are to identify factors that could potentially inhibit or enhance long-term productive use of disturbed land and to maximize the usefulness of reclaimed lands in this region. Included in the experimental design are evaluations of various methods of overburden removal, spoil handling, spoil placement, spoil pile modification, surface amendments, irrigation, and various revegetative techniques.

2. Southwestern Region

The ANL program includes three study areas in the Southwestern Coal Region; one associated with the Black Mesa mine near Kayenta, Arizona, and the other two in Northern New Mexico associated with the San Juan and Navajo Mines. As with other ANL studies these projects are cooperative ventures with the mine operators, and in each case regional universities are major participators in the research.

2.1. Black Mesa Mine Site

This project is a feasibility study that involves a cooperative effort between the Peabody Coal Company, Arizona State University, and ANL (Carter and Cameron) in an evaluation of water harvesting techniques. The research utilizes a study initiated in 1974 by the University of Arizona to explore the coupling of recontoured spoil areas with impoundments to provide water for improved land use after mining. Should the results appear promising, a larger area of more realistic size would be developed to explore large-scale water harvesting possibilities to provide for family subsistence, crops, irrigation for reclamation purposes, livestock use, as well as rearing fish. Water availability is a key factor in reclamation efforts since precipitation occurs primarily in short duration, high intensity rain. Water harvesting techniques offer considerable benefit in terms of lowering the overall impact of regional development. The expected outcome of this research will be a model to predict optimal land allocations for water harvesting, crop production, and grazing based on water runoff and other environmental restrictions.

2.2. San Juan Mine Site

This project (Carter and Cameron) involves the Western Coal Company, New Mexico State University, and ANL. The area is located in San Juan County, New Mexico.

The main thrust of this research is related to problems in establishment of vegetation due to high salinity of the topsoil.

2.3. Navajo Mine Site

This project (Carter and Cameron) is in the conceptual stage. It will combine plant breeding and selection techniques with plant growth, development, reproduction, and successional studies of plants and plant communities in a medium- to long-term effort to produce varieties useful to insure self-perpetuating landscapes on reclaimed areas where soil moisture and related stresses may limit revegetation. The study will be a joint effort between the operator, Utah International, and ANL.

3. Central Region

Two study areas related to the interagency program are located in the Central Region, one near Morris, Illinois; the other near Staunton, Illinois.

3.1. Goose Lake Prairie State Park Site

This site in Grundy County is about 50 acres in size. Although mining operations ceased over 30 years ago, 75 percent of the area remains barren due to strongly acidic mine spoils and continual erosion of the surface. This project (Carter and Cameron) will involve a demonstration effort in cooperation with the State of Illinois, coupled with an ANL research program to evaluate the effectiveness of reclamation activities that include the use of chemical soil stabilizers and soil amendments such as lime, sewage sludge, fly ash, and straw. The plan is to revegetate the site with prairie grasses, as is being done in an adjacent state park.

The experience gained from this project will guide restoration efforts for similar problem areas in the state.

3.2. Staunton Deep Mine Refuse Site

This site in Macoupin County, like the Goose Lake Prairie State Park Site, represents a common set of environmental problems related to abandoned coal mines and refuse piles. Over 6,000 acres of land in Illinois alone are covered with barren, acidic refuse piles. Similar areas exist in other parts of the Central Region. Macoupin County contains 100 such sites. These waste areas represent significant sources of pollution to surrounding areas. This project (Cater and Cameron) will represent another cooperative effort by ANL, in this case with the State of Illinois and the Illinois Institute for Environmental Quality, in an effort to establish better methods for disposal and utilization of wastes and restoration of affected lands. The results are expected to be of considerable benefit to mine operators in reclamation of land and to legislators in drafting legislation.

The research/demonstration project will include assessment of infiltration, run-off, and quality of water on the site and on adjacent, impacted areas. Both laboratory and field experiments will be performed to evaluate effects of chemical and physical treatments on plant growth and establishment, and on microbial transformations of nitrogen and sulfur compounds.

4. Other Activities

Two other tasks from the interagency program are included in this area, one relating to oil shale extraction, the other to data management. The oil shale study, conducted by the Pacific Northwest Laboratory (Routson), involves development of a model to predict movement (either solvent or solute) through spent shale or disturbed strata under areas where shale has been extracted.

Data storage and management systems (software) being developed in a joint effort between Oak Ridge National Laboratory (Strand) and ANL will ultimately provide two-way exchange of information between Federal agencies, other public agencies, the professional community, and the coal industry. The system is planned to permit storage and retrieval of bibliographies and abstracts of reclamation research programs, data, or reports including evaluations and comments. The level of funding for this task is not commensurate with the broad scope and somewhat idealistically ambitious objectives of the working groups' report. (This is unfortunately the case with many interagency tasks.) Consequently, only by merging efforts supported by this program with current programs can these objectives be approached or attained.

TRACE CONTAMINANTS FROM COAL COMBUSTION AND PROCESSING

The 1976 level of coal use in the United States was approximately 600 million tons, and forecasts indicate that this could double by the late 1980s as the nation turns to coal to alleviate dependence on foreign oil sources. Most of the environmental concern has been focused on sulfur dioxide, sulfates, and particulate emissions. This has resulted in great pressures for removal of sulfur prior to combustion and for development of more efficient control technology systems. The projects in this program area deal with another growing concern of whether trace elements, which are found in coal, constitute a potentially serious long-term environmental problem.

The composition of coal varies considerably, and there is no typical coal composition. Some of the trace elements of concern are cadmium, mercury, selenium, arsenic, lead, chromium, copper, and zinc. Trace element concentrations in different coals and even coals from the same area may vary as much as two to three orders of magnitude for a given trace element. However, 10 ug/g is a common concentration for many of these elements. Such a concentration could result in the annual release of 6,000 tons of such hazardous elements as mercury, arsenic, and cadmium at the current level of usage. The projects included in this program are designed to determine the characteristics, transport, and fate of these trace elements in coal following combustion or conversion to synthetic fuels, and their effects on various compartments of the environment.

Some of the projects address the determination of which elements are released via a utility stack and how they are distributed in the vicinity of the plant. Another group of projects deals with the determination of trace elements in the residual fly ash and furnace ash and their mobilization following burial at disposal sites. Closely related studies address the way in which any mobilized elements are retained by different type soils.

Another aspect of this program is consideration of the manner in which the trace contaminants are cycled biogeochemically and the extent to which they are concentrated by aquatic and terrestrial organisms. In addition, some of the projects deal with effects on plant and animal species in several regions of the country.

Finally, two of the projects will attempt to identify biological indicators which would serve as early warning systems for detection of deleterious effects.

The results of these investigations are of necessity quite preliminary and will be discussed under five headings: (1) transport and fate of trace contaminants released to the atmosphere, (2) studies on trace elements in fly ash, (3) biological effects, (4) biological indicators, and (5) coal conversion trace contaminant studies.

1. Transport and Fate of Trace Contaminants Released to the Atmosphere

One of the major pathways for introduction of trace contaminants into the environment is via particulate releases to the atmosphere from combustion stacks followed by deposition on the surrounding environment. In one study being conducted at the Savannah River Laboratory (Crawford), measurements are being made of the trace element composition of the plant fuel, ash, and stack discharge to develop material balance data on trace contaminants released from a large power plant which has operated for about 20 years without an electrostatic precipitator. Measurements are also being made of the concentration of trace contaminants in soil, vegetation, mammals, micro-organisms, and aquatic organisms along several transects through the plant. These data will be correlated with source term and meteorological data in the overall assessment.

Another feature of this project will be the use of fly ash on southeastern U.S. forests and field crops to determine whether such practices could be beneficial. A number of field plots will be established and the effect of fly ash application measured.

The Colstrip study (Gordon and O'Toole) mentioned in the first section (involving the Ames Laboratory, the Pacific Northwest Laboratory, the University of Montana, and Montana State University) is similar in several respects to the study at the Savannah River Laboratory. Several sampling sites have been established around the Colstrip operation. Fluoride, SO_2, and particulate samples are being collected. Baseline data indicate that the air quality in the region is currently very good. Samples of vegetation and soils have also been collected as part of the baseline program and analyses for various trace contaminants are in progress.

Aquatic ecosystem studies have involved the selection and description of various water impoundment areas for pollution assessment and evaluation of existing water quality. Biological sampling of the aquatic ecosystems has been initiated and macrophyte species have been harvested and identified in preparation for pollutant uptake studies. Calculation of the macrophyte production in a number of the impoundment sites is underway.

2. Studies of Trace Elements in Fly Ash

Three projects deal with the mobilization and transport of trace elements from fly ash buried at various disposal sites. One is at Notre Dame, one at State University of New York-Fredonia, and the third at the Savannah River Ecology Laboratory.

The project at Notre Dame (Theis) deals with the leachability of trace elements in fly ash through soil columns. Included are both laboratory and field studies at actual disposal sites using a variety of soil types and coal ash. The rate and extent of fixation of these leached elements by different soils is also under study. These latter studies involve equilibrium-type measurements of adsorption isotherms and dynamic column studies in which "breakthrough" measurements are made. In the field, experiments and test wells have been drilled to permit validation of laboratory findings and models.

The study site for the SUNY-Fredonia project (Wood) is in Chautauqua County, New York. The work is focused on effects on aquatic systems related to principal fly ash dumps. The initial phases of the work are directed toward establishment of analytical methods and procedures to be used in monitoring of stream water, lake water, ground water, sediment, and biota.

The project at the Savannah River Ecology Laboratory (Smith) has two facets. One like the SUNY project deals with impacts of fly ash disposal on aquatic biota. Samples have been taken of sediments and organisms from locations at various distances from the main disposal site. The area is characterized by acid "Blackwater" streams and cypress-gum swamp, two biological systems common to the southeast. The second facet of this work deals with the aerial deposition of fly ash from the power plant stack onto a small spring fed pond with special emphasis on trophic level bioaccumulation. A mass balance for trace contaminants will be constructed using input and output data estimates from rain gauge and outfall weir data.

3. Biological Effects

The third group of projects deals with the ecological effects of trace contaminants. Most of the research in this section is concentrated in the West where the effects can be exacerbated by limited water availability.

One study site is in the Mojave desert where the Laboratory of Nuclear Medicine and Radiation Biology, University of California-Los Angeles (Turner) is studying the concentration of trace elements in animals and plants around the Southern California Edison's Mojave Generating Station. Initial emphasis is on comparison of uptake of different elements on an intraspecies and interspecies basis. Work is closely coordinated with similar work being conducted at Four Corners, New Mexico, by the Los Alamos Scientific Laboratory (Johnson).

The third project (Wolf) in this group, conducted by the Pacific Northwest Laboratory (PNL), is directed toward the effect of coal-related pollutants on the behavioral patterns of fish. An extensive review has been prepared which estimates the concentration of various pollutants from coal conversion processes and evaluates their potential toxicity. It also covers the various behavioral pattern studies used to determine sublethal effects. Instrumentation is being adapted and developed for the effects studies. One instrument being tested for use in behavioral effects is the polygraph.

4. Biological Indicators

The first project, which is with the Virginia Polytechnic Institute (Cairns), is concerned with techniques for measurement of the effect of pollutant stresses on the functional processes of various trophic levels in aquatic communities. The program is broad and encompasses both laboratory and field investigations. The general areas being examined include:

1) Structural and functional aspects of autotrophic and heterotrophic attached microbial communities in lotic systems. A major emphasis on the development of techniques for measuring the effect of stress on the assimilation and metabolism of carbon, sulfur, and nitrogen.

Six artificial experimental streams, designed and constructed at Appalachian Power Company on the New River in Virginia, will be used to evaluate the sensitivity of functional parameters to various energy-related pollutants (copper, chlorine, etc.).

2) Use of protozoan invasion and extinction rates to assess the eutrophication process as related to energy development. Studies have been initiated in a series of lakes in Northern Michigan which have been found to be in various degrees of eutrophication and in Smith Mountain Lake near Roanoke, Virginia.

3) Detrital processing by macroinvertebrates to assess the effects of stress on community function. The general objective of this approach is to evaluate the potential for using detritus processing rates as a pollutant stress assessment technique. Three field sampling stations have been established near the Glen Lyn Power Plant on the New River in Virginia. Observations will be correlated with changes in temperature, photoperiod, flow regime, and timing and sequencing of the macroinvertebrate community.

4) Development and testing of methods to determine the functioning of plankton communities. This sub-project is concerned with the effects of temperature, slimicide, and physical shock on zooplankton function as affected by power plant cooling systems. Laboratory studies have been started on *Daphnia pulex* and field experiments will be initiated shortly.

A second project, at Lawrence Berkeley Laboratory (Harte and Levy), is utilizing microcosms to evaluate biological indicators. Preliminary work has been directed to defining conditions for establishment of microbial communities of the diversity encountered in natural systems and to selection of larger zooplankton and fish. Several novel experiments are under study to evaluate hypothesized stability indicators. These include the activity levels of the major enzyme groups associated with decomposition and mineralization and biochemical indicators which may characterize the healthiness of the microbial decomposer.

5. Coal Conversion Trace Contaminant Studies

Three projects (Gehrs) conducted at Oak Ridge National Laboratory are concerned with the transport and effect of trace elements and trace organic pollutants generated or released during coal conversion to synthetic fuels. Included is research on the chronic, low-level effects of contaminants as well as investigations into the persistence, fate, transformation, and food chain kinetics of these substances.

OFFSHORE OIL EXTRACTION AND RELATED PROBLEMS

The major part of the effort in this program is centered in the Puget Sound region under the direction of scientists at the University of Washington and the Pacific Northwest Laboratory (Carpenter and Templeton). The major objective is to assess the potential effects of long-term exposure to petroleum-derived hydrocarbons on selected ecological communities in Puget Sound. The studies combine laboratory and field experiments. The program is closely coordinated with NOAA's program in Puget Sound.

Also at PNL (Vanderhorst), scientists are looking at the laboratory response to mysids and amphipods (later Dungeness crabs will be included) to varying concentrations of specific hydrocarbons and aqueous phase petroleum. They plan to assess the effects of soluble petroleum on key factors in the life cycle of these organisms.

In coordination with these laboratory studies, an extensive field sampling program will be conducted in Puget Sound (Bean). Emphasis will be placed on Cherry Point - Anacortes and Port Angeles, two locations that are receiving oil wastes from refineries. Scientists will analyze petroleum contaminants in water, organisms and sediments. These data will be compared with field samples from relatively pristine Puget Sound localities such as Sequim Bay. Also included in the field program are studies to examine the potential biological availability and effects of petroleum hydrocarbons bound to sediments. The effects of continuous exposure to low levels of petroleum hydrocarbons released from sediments is being investigated by following the compositional changes of established and recruited infauna populations.

An important contribution to the Puget Sound program is being conducted by University of Washington scientists who are determining the distribution of the natural versus man-made hydrocarbons in local marine organisms (phytoplankton, zooplankton, neuston) and in sediments and water. Sediment cores have been dated with a lead 210 technique which leads to a time history of hydrocarbon input to the sediments. The investigators will also use the $^{13}C/^{14}C$ ratio to separate recently biosynthesized hydrocarbons from ancient fossil fuel hydrocarbons. Presently, the laboratory at the University of Washington will handle all of the low-level analyses ($> 10^{-3}$ ppm) for hydrocarbons using liquid chromotography and ultraviolet fluorescence techniques. Guidance on the use of these technologies has been furnished to scientists at NOAA and at PNL who are cooperating in the total program.

A smaller study has been initiated at Lawrence Livermore Lab (Spies). Investigators there are comparing the benthic community structure at two sites in the Santa Barbara oil lease area: one site is an active oil-seep area; the other is in a clean area untouched by oil contaminations. Ten replicate cores obtained by divers are collected each two months. Each area is clearly marked for easy and repetitive location. The intent of this study is to identify differences in the benthic community structure between these two areas

The investigators at LLL also plan to initiate studies of the effects of drilling on selected benthic organisms with emphasis on the ways in which organisms assimilate the toxic components of drilling muds.

Another part of this program is concerned with the transport and dispersion of refinery wastes in freshwater coastal regions. Funds were used to supplement a major program at Argonne National Laboratory (Harrison) in coastal transport and diffusion in southern Lake Michigan. The dynamics of oil-fouled receiving waters are being examined in a series of experiments conducted off the Calumet Region of Illinois and Indiana where five oil refineries discharge oil processing water into the Lake via the Indiana Harbor Canal.

In a given experiment, a quantity of canal water is tagged with a small amount of an inert, non-toxic rare earth in aqueous solution. At the same time and place, a quantity of oil-refinery waste is released; this release is tagged with an oil-soluble solution of a different rare earth. Both tagged quantities move into the Canal and into the Lake, dispersing in the normal fashion.

Several such experiments are planned under different environmental conditions which will be useful for adjusting dispersion coefficients in numerical models of oil waste transport. These data will be used to test a numerical model of nearshore water transport developed at Case-Western University under EPA sponsorship.

IMPACTS ASSOCIATED WITH OFFSHORE POWER PLANTS

The coastal oceanography program at ERDA supports a wide variety of research projects on the transport and fate of radionuclides and toxic substances on the continental shelf and in estuaries. The ERDA cooling system program and this effort are both aimed at development of knowledge of how substances such as Cu, Zn, heavy and potentially toxic metals, and tritium are moved and recycled in the nearshore region, and their possible effects on economically or ecologically important organisms. This knowledge is directly applicable to material likely to be ejected from coastal and offshore power systems.

The EPA pass-through funds for projects included in this program are integrated with our coastal oceanography program in transport of pollutants in estuaries and on the continental shelf. One of our principal contractors (Cross) is the Atlantic Estuarine Fisheries Center (NOAA) at Beaufort, North Carolina, which is working to (1) develop a dynamic model of the cycling and fate of copper, nickel and zinc in coastal waters in North Carolina and (2) determine the effects of dissolved organic compounds originating from watersheds and marshes on the physical transport and biological availability of copper to marine organisms, particularly phytoplankton and larval fish.

Work has already begun on establishing baseline concentrations of nickel, copper and zinc in Onslow Bay sediments, pore waters, and benthic fauna. Cruises will begin this spring to collect samples for analysis of copper, nickel and zinc in water within Onslow Bay, including the area near the ocean outfall of the Brunswick Nuclear Generating Plant. Experiments will be conducted in the laboratory to assess the environmental factors controlling sediment-water exchange of these metals.

Complexation of copper by natural organic matter is to be investigated with respect to the following parameters: concentration and chemical composition of dissolved organic matter, concentration of copper, presence of competing metals, acidity, salinity, temperature, and time, i.e., kinetics. Ultimately, we wish to be able to estimate spatial and temporal variations in copper speciation and to determine at least some of the important factors that control copper complexation in natural waters.

So far, research indicates that only a minute fraction of the total copper in estuarine is present as free cupric ion. Calculations show that the high degree of copper complexation in the water cannot be accounted for by the formation of inorganic complexes, thus indicating that the predominant portion of the copper is present as organic complexes.

Complexation of copper by dissolved organic matter is highly dependent on pH, apparently due to competition between hydrogen ions and cupric ions for coordination with organic ligands. River pH has been measured at values as low as 5.4 indicating rather large spatial and temporal variations in this parameter. Changes in pH should be an important parameter affecting natural copper complexation in the Newport River and estuary.

Chelation reduces copper toxicity and biological availability. Experiments are being designed to determine the sensitivity of fish eggs (spot, croaker, flounder and silversides) to both free cupric ion and to copper complexes. Preliminary results from this investigation suggest that fish eggs are sensitive only to free cupric ions and that these levels of toxicity are similar to those observed for algae.

This work, just begun, is important to our study of the complexation of copper to natural ligands and to determine what effect this process has on trace metal cycling, including biological availability. Such information is of great importance in predicting the impact of elevated levels of copper and other heavy metals introduced by power plants on fishery resources.

POWER PLANT COOLING SYSTEMS

As indicated in the introduction, pass-through funds in the power plant cooling systems area have been applied in toto to augmentation of a substantial program already in place. This program is currently operating at a level of about $3.8 million per year as shown in Table 2. The conceptual framework of the ERDA cooling systems program is given in Figure 1. Indicated on the figure are areas where four pass-through projects classified in this program are focused. These projects are discussed below.

1. Effects of Temperature on the Behavior of Marine Invertebrates

Several years of experience have made it increasingly apparent that the circulation characteristics of most Steam-Electric-Station (SES) sites are such that direct mortalities of important organisms due to waste heat discharge are not likely to be of quantitative significance, since the areas impacted by an appreciable temperature increase are generally quite small. ERDA has accordingly supported for several years a program on the effects of small temperature increases on various parameters of fish behavior, conducted at the National Marine Fisheries Service Laboratory at Sandy Hook, New Jersey (Olla). The program is directed at evaluation of the importance of sublethal effects.

Pass-through funds are being used to expand the program to include the effect of temperature increase on the behavior of marine invertebrates representative of mid-Atlantic coastal environments. Feeding activity, shelter dependence, and social interactions such as aggression and territoriality are representative of the behavioral measures studied. The blue-crab, Callinutes sapidus, has been selected as the initial species for evaluation, and current efforts are directed at the establishment of baseline data for crabs maintained in laboratory aquaria.

2. Synergistic Effects on Invertebrates

Some of the more significant impacts of once-through cooling systems in aquatic environments may be manifested in the development, composition and community metabolism of fouling communities as influenced by toxicants such as copper leached from the condensers or chlorine and its derivatives associated with fouling control procedures. Scientists at the Pacific Northwest Laboratory's marine facility at Sequim, Washington, are utilizing pass-through funds to evaluate the significance of these kinds of effects (Thatcher). Polyvinylchloride substrata are used in situ to permit development of normal fouling communities. Then they will be exposed in the laboratory to the following regimes: (1) unfiltered ambient sea water; (2) heated sea water; (3) heated sea water and chlorine; (4) heated sea water and copper; (5) heated sea water and chlorine and copper; (6) ambient sea water and chlorine; (7) ambient sea water and copper; and (8) ambient sea water and chlorine and copper.

To date exposure panels 100 cm^2 and 400 cm^2 in area have been placed in the Straits of Juan de Fuca 40 feet below mean low water. They are inspected once a month with SCUBA; temperature is continuously monitored. Initial panels are being transferred to the laboratory at the time this is being written. Ultimately laboratory results will be verified at a Pacific Gas and Electric plant site and estuarine sites for submerged panels will be established at Willapa Bay or Gray's Harbor. A typical panel is illustrated in Figure 2.

3. Chemical Effects of Chlorine and Derivatives

Although recent estimates suggest that only a small percentage of the total chlorine added to the Nation's waterways each year enters in the effluent from once-through cooling systems, interest in potential problems arising from power plant cooling water chlorination has increased dramatically. This is particularly true for marine and estuarine environments where little information exists, and the possibility of interactions with high ammonium ion concentrations and other factors is great.

Pass-through funds are being applied to the expansion of an ongoing program also at the Pacific Northwest Marine Laboratory at Sequim, Washington, to support bioassay determinations for LC_{50} chlorine dosages for a spectrum of marine organisms (Templeton). Preliminary experiments on oyster larvae, Dungeness crab eggs, coon stripe shrimp eggs, and amphipods have been completed. Replications of these determinations are planned as well as experiments on eggs and larvae of flounder, herring, smelt, and sandlance. A substantial portion of the overall effort is devoted to resolution of problems in the analytical techniques for determination of "total residual chlorine."

4. Condenser Effects

Direct mortality to organisms passing through power station cooling systems may represent the most significant impact on the biota of receiving water supplies. Significant damage can be caused by purely physical aspects, such as abrasion and pressure changes, of cooling system passage.

Previous work at Oak Ridge National Laboratory with an experimental condenser loop has indicated that condenser passage itself is not a significant source of mortality, and that the probable site of most physical damage to plankton may be the high speed, high volume pumps used to supply the cooling system. This portion of the ERDA cooling systems program is devoted to construction of an experimental pump-condenser loop system which will be used to determine the source of mechanical damage to typical freshwater and marine ichthyoplankton. Attention will be focused on features of pump design and operation such as speed and net positive suction head (Coutant).

Specifications and design criteria for construction of the experimental system have been completed and bids received for a scaled down model of a condenser-pump system. The program is on schedule and initial experimentation will begin as planned this spring.

5. Other Projects

One other project unrelated to the above but included in this program for administrative purposes deals with atmospheric effects of cooling towers (Gifford). This research which deals with the atmospheric effects of large cooling towers, operating singly and in clusters, and is being conducted by NOAA's Atmospheric Turbulence and Diffusion Laboratory (ATDL) at Oak Ridge, Tennessee.

A numerical cloud growth model is being constructed drawing on previous experience at ATDL and elsewhere. The sensitivity of the model to parametric variations will be investigated. The model predictions will be compared with field data. Wind tunnel studies will be used to examine the effects of the geometry and placement of cooling towers in simulated environmental settings on the behavior of the plumes. Problems of plume down wash and interactions between plumes are being investigated.

The possibility of large heat and moisture fluxes from energy centers affecting local and regional weather conditions is being examined theoretically. Field experiments are being considered.

ALASKAN OIL

As a result of the Prudhoe Bay, Alaska oil strike in 1968, there was thought to be about two billion barrels of crude oil and some 7.4 trillion cubic feet of natural gas in that field. By 1973 the proven reserves of crude oil for the U. S. and Canada, except the Arctic, were estimated to be 1.3 billion net barrels. Currently, Alaska's Arctic Slope is estimated to have something under 10 billion barrels of crude oil and about 22.5 trillion cubic feet of natural gas. None of the values given for Alaska include estimates for presumed Outer Continental Shelf reserves. Thus, Alaska will figure importantly in the Nation's future petroleum production/planning.

The Atomic Energy Commission was involved for many years in ecological research and studies of man's impact on the arctic. For example, the study of the Cape Thompson region resulted in the most detailed characterization of any arctic region yet published. This experience and related projects were inherited by ERDA and form the core for the future research program related to development of Alaskan resources.

Given this potential of the region combined with the difficulties of technology, exploitation, and production in this remote and rigorous environment, the questions in need of answers are many and diverse. ERDA has responsibility for three tasks related to these problems, as follows:

1) Oil persistence in the tundra and its impact on the below-ground ecosystem,

2) Effects of oil on tundra thaw ponds, and

3) Effects of construction on tundra lakes.

Although these studies were funded June 1, 1975, most of them could not be effectively started prior to late June. Therefore, few results are available and those which are available are only preliminary in scope.

1. Oil Persistence in Tundra and Below-Ground Impact

1.1. Technical Discussion

The presence of natural oil seeps in the Arctic have been known for several decades. Their existence certainly exceeds several hundreds of years and perhaps thousands. They provide somewhat of an index to the impact of oil on the tundra and adaptation modes or processes within the microbiotic communities surrounding such seeps. The natural fate of oil pollutants involves physical, chemical, and biological processes. The biodegradation depends on the oil's composition, the microbial community, nutrient levels, temperature, soil respiration rates, etc.

Soil microorganisms are essential components of Arctic ecosystems, especially in elemental transformations including the cycling of carbon, nitrogen, phosphorus, and sulfur. These cycling processes may be altered by pollutants.

1.2. Program Discussion

The contractor for this research is Virginia Polytechnic Institute and State University (Miller). Study sites were selected at Barrow and at the IBP Tundra Biome study site at Footprint Creek near Barrow. Both are on the coastal plain. In order to assess long-term effects, natural seeps will be visited near Cape Simpson (coastal plain) and old spills will be examined at Cape Thompson (coastal plain) and Umiat (foothills).

Objectives are to:

1) Monitor species composition of filamentous fungi, yeasts, and bacteria in oil treated areas.

2) Follow impact of oil on fungi, bacteria, and plant roots through one growing season.

3) Monitor physiological changes in microorganisms with emphasis on altered respiratory quotients and changes in energy availability, determine how changes which occur affect soil-water relationships, and relate the changes to rate of oil degradation.

4) Isolate and culture species of bacteria and fungi able to use oil as a substrate or grow and function in areas of high oil pollution.

To date there has been documentation of a significant lowering of populations of fungal biomass exposed to Prudhoe crude, marked depression of mycorrhizal root activity, shifts in soil bacteria, and a strong increase in soil respiration following treatment (this response is usually followed by a drop in activity).

Oil may penetrate to depths of 8 cm in soil or may stay on top of the soil with little mobility, apparently as a function of the microvegetative cover. At a highly contaminated natural oil seep at Cape Simpson, only a single plant species, Dupontia fisherii, remains. Bacterial populations are high, fungal populations are low, and physiological differences in the root action of Dupontia have occurred, allowing it to exist in the highly contaminated area.

2. Effects of Oil on Tundra Thaw Ponds

2.1. Technical Discussion

In 1970 a rather heavy concentration of oil, 10 l/m^2, was spilled on a tundra pond near Barrow, Alaska. Results of that spill showed massive organism die off and a slow recovery. The phytoplankton species composition changed and has not returned to the pre-spill status in the five years to date. Zooplankton has returned to about normal densities and diversity while the aquatic insects are still at different densities and species composition as compared to the control ponds. The littoral margins (about 33 percent of the pond area at high water) are still covered with a tar-like residue and the macrophytes have not returned to this area. This presents a condition that merits a comparative analysis with ponds receiving much smaller doses of oil to determine differences in mortality and recovery rate.

2.2. Program Discussion

North Carolina State University (Hobbie) is responsible for this research. Ponds near Barrow were used as study sites.

Within the above general framework, the objectives of this study are to determine:

1) The process by which an oil spill changes species composition of phytoplankton.

2) The process by which an oil spill kills zooplankton and whether all species are equally sensitive.

3) the concentrations of oil necessary to kill plankton species and the sublethal effects produced by oil.

4) The process that prohibits reproduction in benthic animals.

5) The effect of oil on bacterial numbers in plankton and sediments.

6) The long-term effect on rooted aquatic plants.

7) The rate of degradation of crude oil and its components parts in arctic ponds.

The primary interests were in recovery times and toxic effects of small spills. Two ponds received concentrations of 0.12 l/m^2 and 0.24 l/m^2, respectively, of Prudhoe crude in 1975 to compare with the 1970 spill. Within eight hours post-spill the ponds showed a marked increase in phytoplankton response (such a response is similar to that produced by a shock or stimulus to phytoplankton). About two weeks later, the following effects were observed:

1) Macrophyte growth was unaffected.

2) There was no change in phytoplankton production or biomass, but species composition change was in the same fashion as in the 1970 spill.

3) Zooplankton disappeared.

4) Litter decomposition was inhibited.

5) No effect was detected on bacteria.

6) Large numbers of insects were killed and reproduction of species which lay eggs on water surfaces or marginal vegetation stopped. Species which deposited eggs pre-spill (in some cases three years earlier) showed normal emergence.

7) Oil disappeared in an exponential fashion from spill areas.

3. Effects of Road Construction on Tundra Lakes

3.1. Technical Discussion

Road construction and maintenance in the arctic imposes severe difficulties both in terms of providing a stable, relatively permanent structure and of minimizing serious impact on adjacent undisturbed tundra. A gravel substructure must be built. Grading is kept to a minimum. Because of road structure, few drainage pipes under the road are used. Thus, snow melt ponds tend to form. Further, dust from the roads tends to cause earlier snow melt and affect the suddenness of the summer snow melt.

A major question concerns the effects of altering watershed drainage increasing sedimentation as a result of road construction. Such effects are associated with the dumping of large amounts of gravel into water, leaching of minerals from the gravel, increased sediment loading within lake waters, and alteration of the sediments on lake bottoms.

The two previous studies on lakes suggest the nature of the range of disturbances that can be expected to occur in arctic lake systems. Baseline data are needed from lakes where no human disturbance is yet involved to better understand the quantity or quality of potential changes.

3.2. Program Discussion

This project (Alexander), which is conducted by the University of Alaska, was designed to answer certain questions on not only the biological effects of increased turbidity on lakes, but also on physical and biological alterations. In part, the objectives complement the studies on oil spills on ponds. Those biological parameters that could be most easily measured concern changes in microbial, benthic, and plankton populations or in primary production. Both quality and rate of food intake by zooplankton or visual-feeding fish may be altered.

Physical and chemical alterations are most easily demonstrated by documenting runoff and water turnover changes, light penetration, chemical cycle composition (pH, dissolved oxygen, etc.) changes and effects on thermal regimes or geochemical budgets.

A survey of the highway along the pipeline route revealed that there were 83 bodies of water adjacent to the highway. Of these, 26 percent were thaw ponds or lakes (caused by melting of ground ice), 25 percent were block drainage ponds (created along roadside by the road construction process), 24 percent were beaded stream ponds, 12 percent were old ox bows or meanders of the river, 8 percent were glacial or kettle lakes, and 5 percent were of other types. The seasonal chemistry was intensively studied in block drainage, thaw, and meander ponds. Ponds on the coastal plain were alkaline while those in the foothills were acid. Extensive sampling showed that block drainage ponds created within the past year had higher primary productivity than large bodies of water such as Toolik Lake. Dust effects were minimal beyond about 50 meters from the road, but within that range could be markedly reduced.

As a means of evaluating the effects of man-caused water turbidity and assessment of suspended sediments two other lakes unaffected by man will be used. Lakes Peters and Schrader on the north side of the Brooks Range are being used to assess effects of suspended sediments. The lakes are situated in a narrow glaciated valley, and are joined by a narrow channel. They have a common source yet they contrast strongly in turbidities because of their relative positions. In addition, productivity and phytoplankton regimes have been previously studied in these lakes providing baseline information for comparative purposes.

The backbone of the study will be to make sediment load determinations in the lakes along transects and correlate them with the spectral band sensed by special water penetrating color film (Kodak SO-224) in aerial photographs and high altitude ERTS imagery. Trace metal and nutrient distribution and limnological factors related to light penetration and primary productivity will be measured.

PROGRESS AND FUTURE DEVELOPMENTS

All of the projects described herein were initiated during late June to July of 1975. In most cases progress has been limited to site reconnaissance and survey, and development of detailed experimental designs. In no case was a complete growing season available for implementation of research plans.

PROJECT REFERENCES

Alexander, V., University of Alaska, Fairbanks.

Bean, R. M., Pacific Northwest Laboratory, Richland, Washington.

Cairns, J., Virginia Polytechnic Institute, Blacksburg, Virginia.

Carpenter, R., University of Washington, Seattle, Washington, and W. L. Templeton, Pacific Northwest Laboratory, Richland, Washington.

Carter, R. P. and R. Cameron, Argonne National Laboratory, Argonne, Illinois.

Crawford, T. V., DuPont de Nemours (E.I.) & Co., Savannah River Laboratory, Aiken, South Carolina.

Cross, F. A., National Marine Fisheries Service, Beaufort, North Carolina.

Coutant, C. C., Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Gehrs, C. W., Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Gifford, F. A., Atmospheric Turbulence and Diffusion Laboratory (NOAA), Oak Ridge, Tennessee.

Gordon, C. C., and J. O'Toole, University of Montana, Missoula, and Ames Laboratory, Iowa.

Harrison, W., Argonne National Laboratory, Argonne, Illinois.

Harte, J., and D. J. Levy, Lawrence Berkeley Laboratory, University of California, Berkeley.

Hobbie, J. E., North Carolina State University, Raleigh, North Carolina.

Johnson, L. J., Los Alamos Scientific Laboratory, Los Alamos, New Mexico.

Miller, O. K., Virginia Polytechnic Institute, Blacksburg, Virginia.

Olla, B. L., National Marine Fisheries Service, Sandy Hook Laboratory, Highlands, New Jersey.

Routson, R., Pacific Northwest Laboratory, Richland, Washington.

Smith, M. H., Savannah River Ecology Laboratory, University of Georgia, Aiken, South Carolina.

Spies, R. B., Lawrence Livermore Laboratory, University of California, Livermore, California.

Strand, R. H., Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Templeton, W. L., Pacific Northwest Laboratory, Richland, Washington.

Thatcher, T. O., Pacific Northwest Laboratory, Richland, Washington.

Theis, T. L., University of Notre Dame, Notre Dame, Indiana.

Turner, F. B., Laboratory of Nuclear Medicine and Radiation Biology, University of California, Los Angeles, California.

Vanderhorst, J. R., Pacific Northwest Laboratory, Richland, Washington.

Wolf, E. G., Pacific Northwest Laboratory, Richland, Washington.

Wood, K. G., State University of New York, Fredonia.

TABLE 1

ALLOCATIONS OF FUNDS FOR ERDA PROGRAMS ACCORDING TO CATEGORIES OF THE INTERAGENCY WORKING GROUP ON HEALTH AND ENVIRONMENTAL EFFECTS OF ENERGY USE 1/

	Interagency Category						
				Ecological Effects			
Program and Objective Orientation	Air	Transport Water	Soil	Terrestrial	Freshwater	Marine	TOTAL
		($1000s)			($1000s)		
1. Land Reclamation		75	90	235	270		670
2. Trace Contaminants			130	600	770		1500
3. Offshore Oil		310				485	795
4. Offshore Power Plants		175					175
5. Power Plant Cooling Systems	80				200	305	585
6. Alaskan Oil			70		116		186

1/ Based on the report of the working group dated November 1974, prepared for the Office of Management and Budget.

TABLE 2

COMPARISON OF BASE BUDGET AND PASS-THROUGH SUPPORT FOR ERDA PROGRAMS RECEIVING SUPPLEMENTAL FUNDS

Program	Base Budget (Millions)	Pass-Through (Millions)
Land Reclamation	0.5	0.7
Trace Contaminants	5.7	1.5
Offshore Oil	2.6	0.8
Offshore Power Plants	2.1	0.2
Power Plant Cooling Systems	3.8	0.6
Alaskan Oil	0.4	0.2
Coastal Zone Impacts 1/	3.8	0
TOTALS	18.9	4.0 2/

1/ The coastal zone impact program consists of physical and chemical oceanography in the nearshore region. The applications are multitechnological, and the research is in support of four of the programs listed: trace contaminants, offshore oil and related problems, offshore power plants, and power plant cooling systems.

2/ The difference with Table 1 is due to rounding error. The actual value is $3.911 million.

FIGURE 1

CONCEPTUAL FRAMEWORK OF THE ERDA COOLING SYSTEMS PROGRAM

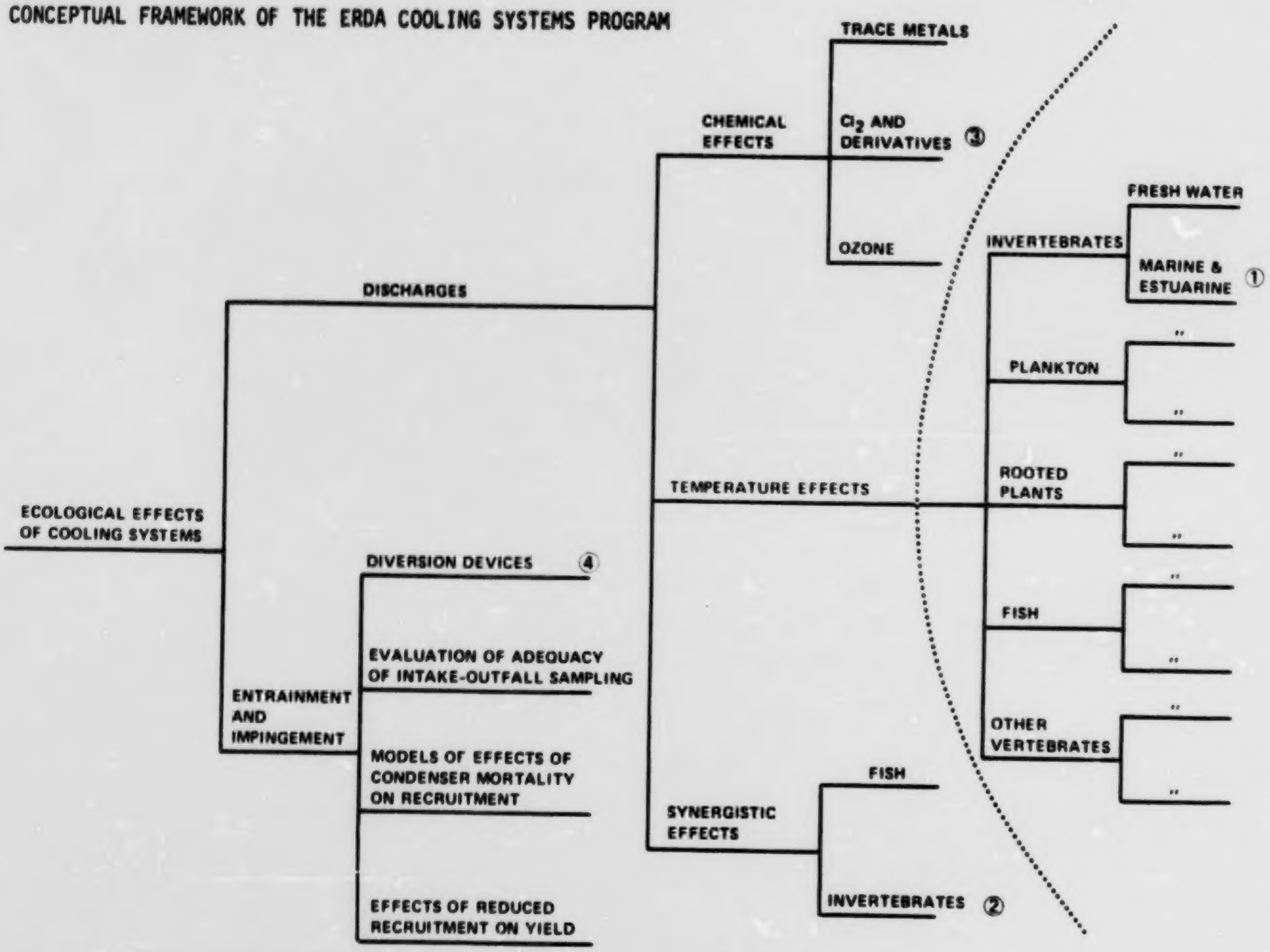
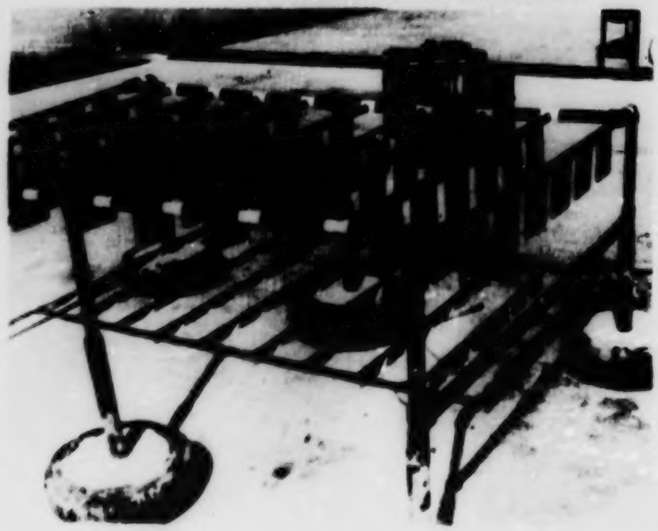

ECOLOGICAL EFFECTS OF COOLING SYSTEMS
DISCHARGES
CHEMICAL EFFECTS
TRACE METALS
Cl_2 AND DERIVATIVES ③
OZONE
TEMPERATURE EFFECTS
INVERTEBRATES
FRESH WATER
MARINE & ESTUARINE ①
PLANKTON
ROOTED PLANTS
FISH
OTHER VERTEBRATES
"
SYNERGISTIC EFFECTS
FISH
INVERTEBRATES ②
ENTRAINMENT AND IMPINGEMENT
DIVERSION DEVICES ④
EVALUATION OF ADEQUACY OF INTAKE-OUTFALL SAMPLING
MODELS OF EFFECTS OF CONDENSER MORTALITY ON RECRUITMENT
EFFECTS OF REDUCED RECRUITMENT ON YIELD

FIGURE 2 ARTIFICIAL SUBSTRATA FOR EXPERIMENTAL STUDIES OF MARINE FOULING COMMUNITIES



(Courtesy C. I. Gibson, PNL)

DISCUSSION FOR MARINE EFFECTS SESSION

Comment from the Floor on Preceeding Rapporteur Presentation: It is difficult to summarize the entire fate and effect of oil on the marine ecosystem. A number of projects and studies have been supported by the American Petroleum Institute, EPA and the U.S. Coast Guard. Much of this work is detailed in the proceedings of the Joint EPI EPA U.S. Coast Guard Proceedings of the Symposium on Oil Spill Prevention Control held in San Francisco, March 1975.

Panel Response: The panel agreed that there is considerable work currently in progress in the area of marine effects of petroleum and petroleum by-products. This work is intended for presentation at the next EPA EPI U.S. Coast Guard Symposium on Oil Spills that will be held later this year. There will be some contradictory evidence which suggests that more sophisticated response measuring is needed to adequately assess the toxicity of various levels of crude oil on the marine organism. Crude oils are only one input to the system, other inputs consist of refined products. Wave and wind conditions in the local ecosystem have a profound effect on fate of oil spills. Mortality of soft-shelled clams transported to an area which had been subject to a spill twelve years earlier will be reported.

Question: Mention has been made of studies showing the effects of chlorine residuals on adult fishes. Are there plans to extend these studies to fingerlings in other species of fish such as shad and other Atlantic Coast species not covered in the studies which have been done or implied by the panel?

Panel Response: NOAA is doing similar work with other fish species although it is not known if shad are included. ERDA is also supporting work at Woods Hole which will involve larval fish as well as different plankton. These studies are directed at the effects of chlorine,ammonia and temperature. Battelle is also doing similar studies involving larval fish, larval crustacean and other juvenile species.

Question: A number of projects have been outlined which relate to Mid-Atlantic Northern warm and cold water areas of the United States. Are there programs addressed to coral reefs or mangrove areas such as occur in Southern Florida?

Panel Response: There is a substantial amount of work which has been reported in manuscripts but not yet published. This work includes the effects of thermal influences on the determination of seedlings in the mangroves along with the composition and structure of ecological communities associated with the mangroves. Reference was made to the First Thermal Ecology Symposium Proceedings for the symposium held in Augusta, Georgia a year ago last spring.

Texas A&M has done extensive work with respect to oil on coral reefs. It is understood that these studies purport to show that particular types of coral are not affected by oil spills even when the tide exposes the coral heads allowing contact with the oil.

EPA is currently conducting work on the effect of low-level, long-term temperature changes on marine organisms. Substantial analysis has been conducted on large amounts of data. This analysis indicates that a temperature increase of slightly more than one degree in an embayment will result in changes in species composition and diversity. Consequently, if power plants are built on bays or estuaries, changes to the biome in these areas can be expected. In the marine area, this temperature increase is sometimes referred to as thermal-pollution. This reference to marine thermal pollution is a misnomer. The local long-term heat addition results in changes in species. New species will come in and old species will evacuate. This is not pollution. However, what happens is unpredictable. Historically, warming has taken place at Cape Cod not induced by man. This has resulted in the green crab, a preditor, devastating the population of soft-shelled clams in the area. Without present knowledge and capabilities, such long-term effects are not predictable, whether resulting from natural or man-induced causes and should be regarded as a crucial issue requiring future research.

Question: A slide displayed during the previous presentation depicted fairly sizeable input of hydrocarbons from river waters into the marine ecosystem. What is the form of the hydrocarbons from river waters to the marine system, and what is the fate and persistence of the pollutant?

Panel Response: A doctoral thesis for a degree earned at the University of Atlanta has been published which is concerned with the fate of polynuclear aromatics associated with river and sewage input into Narragansett Bay. Increases in hydrocarbons were observed in the marine organisms and sediments which decreased markedly at distances of 40 km down the Bay from the shore. The biological process did not appear to result in decomposition of these petroleum products, nor did the petroleum seem to be of immediate harm to the marine organisms in the open sea.

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CHAPTER 6

FRESH WATER ECOLOGICAL EFFECTS

INTRODUCTION

Although the long term energy needs of the U.S. depend on the development of energy sources other than fossil fuels, it is evident that at least for the remainder of the century, we will continue to be heavily dependent on fossil fuels. These needs will require greatly increased use of coal, continued reliance on oil and possible utilization of novel sources and processing technologies such as oil shale and coal gasification. What is not yet apparent is the ecological effects that extraction, transport and conversion of these energy sources will have upon the fresh water ecosystem.

It is recognized that the ecological balance of the fresh water, marine and terrestrial systems are closely interrelated. The aquatic aspects are delineated here as a matter of organizational convenience.

The preservation of adequate water quality is fundamental to the maintenance of the nation's agricultural production, preservation of habitat for fish and wildlife, and the general ecological balance. Competition for these water resources can be expected to increase with demands of agriculture, reclamation and the industrial processes themselves.

In the nineteenth century, sanitary engineering, the technique of managing water supply and waste treatment became the first recognized professional environmental discipline. In contrast, the investigation of more subtle aquatic impacts of thermal and chemical effluents is a fairly recent development in environmental science and engineering.

Special emphasis is currently placed on determining the impacts of energy technologies on aquatic ecosystems. This emphasis will include identification of pollutants released to the system and the effects on aquatic flora and fauna. Also implied is the development of remedial procedures to reclaim damaged areas and the prevention of other ecological damage in the future.

Much of the current reclamation activity is associated with strip mine drainage and the strategies for stabilization and revegetation of lands disturbed at various periods in the past. Preventative attention will include newly developing regions such as Alaska. In recognition of the vast oil reserves estimated in Alaska's Arctic Slope, and the ecological frailty of the area, special attention will be provided. This attention will center on concerns with possible effects of oil spills and pipeline construction activities on arctic lakes, rivers and small watersheds.

THE EFFECTS OF FRESHWATER WITHDRAWALS ON FISH AND WILDLIFE RESOURCES

Robert P. Hayden
Project Leader
Western Water Allocation
U.S. Fish and Wildlife Service

INTRODUCTION

The Fish and Wildlife Service is identifying, evaluating, and attempting to solve energy related problems which threaten the water quality and quantity essential for maintenance of viable aquatic and terrestrial habitats. As we move towards national energy self-sufficiency, competition for the water supply remaining available for utilization can be expected to accelerate and spread from those areas in the Western United States where it is already intense to major portions of the country. Energy related decisions regarding water allocation and use may adversely affect fish, wildlife, and environmental values unless appropriate factual information is provided in a timely manner and this information is carefully considered in planning and decisionmaking processes.

1. Technical Discussion

The preservation of adequate water quality and quantity in existing natural systems is a critical factor in the maintenance of habitat viability for fish and wildlife. This applies not only to aquatic habitats but also to terrestrial habitats where surface water satisfies the consumptive needs of wildlife and supports riparian vegetation. Although water is important in all climatic conditions it is critical in the arid portions of the Western United States where evaporation exceeds precipitation.

In the West, water has long been recognized as the key to economic development as well as habitat preservation. Over the years, numerous projects have been constructed to irrigate arid lands, generate electrical power, and provide drinking and industrial water supplies. During the next decade, competition for the limited water remaining available for allocation and utilization is expected to be intense, particularly for energy development processes. The water allocation and use decisions that will be made in the next few years may adversely affect fish and wildlife. This can possibly be avoided with adequate planning which considers fish and wildlife values.

Western coal and oil shale development will be combined with related chemical, industrial and expected municipal growth to bring great pressures for rapid development of western water reserves. No comprehensive investigations have been made to determine environmental water requirements. Such studies are needed to provide a sound basis for future water allocation decisions. The Northern Great Plains Resources Program and Westwide Study provide some preliminary water requirement data. However, these data are lacking in both the scope and detail required to properly allocate western surface water resources. Analyses stemming from our involvement in river basin planning indicates that adequate knowledge of long-term potential impact on fish and wildlife and the resultant uninformed implementation of action plans could virtually eliminate many entire populations of fish and wildlife.

Water allocation and use decisions involve natural system elements, but occur within a broader social, administrative, legal, economic, and political planning and management context. A basic problem is that although we may recognize that habitat preservation requires adequate water supplies, fish and wildlife are commonly not legally considered beneficial or consumptive uses of water. Therefore, water is frequently allocated to other uses until a stream is dried up or reduced to a small trickle. To insure that fish and wildlife values are fully recognized and considered in land and water resource development decisions, biological assessments must occur within the broader societal planning and management context. We are, therefore, initiating projects and supplying information to decisionmakers on three levels:

(1) Technical

(2) Current Planning

(3) Broad Overview and Management

On the technical level we will be developing methodologies for determining instream flow needs for fish and wildlife, determining the location and habitat requirements of endangered species, and determining the effects on fish and wildlife of water use and development alternatives.

On the current planning level we will be determining the extent and location of unallocated water, establishing fish and wildlife priorities for individual rivers and determining the water quantity needs of fish and wildlife.

On the broad overview level we will initially be trying to determine the new and emerging decisionmaking arenas to enable us to supply decisionmakers with appropriate information in a timely manner. In the long run we will be developing management strategies and improving policy and decisionmaking processes.

2. Program Discussion

The Fish and Wildlife Service's freshwater energy activity is integrated with our other energy programs and regular functions. Our operational elements include a Western Energy and Land Use Team in Ft. Collins, Colorado, and Activity Leaders in our Regional organizations. Staffing objectives have been to create an interdisciplinary capability and appropriate scientific disciplines to adequately address potential energy impacts. For example, in addition to traditional fish and aquatic biologists, we have included a hydrologist, mining engineer, economist, and a political scientist who is expert on water policy, a part of our Ft. Collins Team. The Team will provide a national focus on both the terrestrial and aquatic effects of energy development and work closely with Regional Activity Leaders on regional energy problems. This interaction assures an integrated energy program both geographically and functionally.

We are placing a major emphasis on the development of improved methodologies and tools to assist our regular field personnel in the evaluation of energy development effects on water. Our overall strategy for accomplishing the Service's freshwater program include:

(1) Define the key problems for which solutions are critical and develop a plan of action for solving these problems.

(2) Provide the necessary tools required to minimize water use impacts on fish and wildlife.

(3) Develop improved means to enter into decisionmaking and water resources management processes in order to ensure that fish and wildlife values are fully considered.

(4) Provide information in its most useful form to decisionmakers within the Fish and Wildlife Service, other Federal and State agencies, private developers, and the general public.

During FY 1976 we will be involved in the following major activities:

(1) Initiating a major effort to develop adequate methodologies and field capability to determine stream maintenance flows for fish and wildlife.

(2) Determining fish and wildlife values and characteristics of streams in energy development areas.

(3) Funding studies in the most critical energy development areas to establish interim water needs while methodologies are being developed.

(4) Initiating studies to determine the distribution and migration patterns of selected endangered species in potential energy development areas.

(5) Determining water allocation arenas, physical availability of water, and institutional variables for the Western States.

(6) Communicating initial study results to a broad range of audiences.

A recently completed workshop at Utah State University evaluated the state-of-the-art of methodologies to determine instream flow needs. The study indicated that this field has developed to the point where a concerted effort is needed to refine and apply methodologies of promise to streams under stress from water development. A major effort of the Service during FY 1976 will be the creation of a "Cooperative Instream Flow Service Group" as a satellite to our Western Energy and Land Use Team in Ft. Collins. The Service Group will serve as a focal point for the numerous efforts in determining instream flow needs. It will provide service to practitioners who must use and develop methodologies and prepare, maintain, update, and distribute a handbook on instream flow methodologies, as well as develop improved methodologies.

During FY 1976 we will also be producing a series of reports covering all potential energy development areas and establishing for each area the current status of fish and wildlife, potential fish and wildlife value, and the ranking of waters according to relative value in fish and wildlife terms. The reports will be useful to potential developers in their planning processes to avoid sensitive areas and minimize impact on fish and wildlife resources. The fish and wildlife community can utilize the reports in establishing priorities in planning processes as well as analyzing individual projects and evaluating alternatives.

Late in FY 1976 we will begin a preliminary project to establish the instream flow requirements at specific locations necessary to maintain the viability of important fish and wildlife species present in the Upper Colorado and Upper Missouri Basins. Information on instream flow from specific projects will be assembled and evaluated. The best current available methodologies will be selected within the time and monetary limits of the project. The requirements established will remain our best estimate of instream flow requirements until improved methodologies are developed and applied.

Another major activity will be the initiation of studies to determine the distribution, habitat, and water quality requirements of endangered species in potential energy development areas. This will be a 3-year effort. The project will identify high potential development areas, select priority species to be studied,and identify, locate, and monitor the activities of individual species. The habitat requirements and mitigation alternatives for these species will be assessed. Methodologies will be developed to evaluate the impact of energy and industrial development in these species.

A handbook and guidelines will be published. During FY 1976 studies will be initiated to determine the distribution and migration patterns of selected endangered species.

3. Projection

One of the first functions of our Regional Activity Leaders has been to determine where and how the water use decisions are being made in the States within their Regions. We know these are changing rapidly in some cases. This is essential information to enable us to fund studies which will furnish decisionmakers with appropriate information and to develop methodologies which address the critical questions that will be asked. Concurrently to these determinations we have initiated studies to identify critical research needs. We are now pulling together the results of these studies and examining them in the light of the new and emerging trends in water use decisionmaking identified by our Activity Leaders. We anticipate that a number of high priority information needs will emerge from this process.

The following topics have already been identified:

(1) Evaluation of the impact on ecosystems of alternative energy development programs.

(2) Loss of critical habitat associated with wetlands destruction.

(3) Social aspects in western water law.

INTERAGENCY PARTICIPATION

A substantial portion of the Fish and Wildlife Service's freshwater energy program is being funded by interagency supplemental energy funds. Acceptable results from many of the studies require greater cooperation among State and Federal agencies. In the case of determining fish and wildlife priorities, the Fish and Wildlife Service is initiating the study and providing the mechanism, but the actual determinations will be developed cooperatively with State fish and game agencies providing the major input.

The Cooperative Instream Flow Service Group will be multi-agency in character. Since many agencies have responsibility and interest in instream flow studies, staffing will include State participation, through provisions of the Intergovernmental Personnel Act and participation by other Federal agencies through assignment. Direct services can be provided to a variety of Federal and State agencies. Funding in addition to the basic operating level is being sought from other Federal agencies to broaden the service capability of the group. We anticipate that further financial support will come from the Energy Research and Development Administration, Water Resources Council, U.S. Forest Service, Corps of Engineers, and others.

RESOURCE ALLOCATION

For many years, the Fish and Wildlife Service has actively participated in water resources planning and the evaluation of projects which would affect fish, wildlife, and environmental values. During FY 1975 and FY 1976 the Fish and Wildlife Service budget provided $350,000 for the development of improved tools and methodologies to strengthen the inland aquatic portion of this effort, specifically in energy related aspects. Interagency energy supplemental funds are being used to augment these Fish and Wildlife Service base funds. Total resource allocations since 1975 and projected through 1976 are as follows:

Western Water Allocation Project
(in thousands of dollars)

FY 1975*			FY 1976*		
Base	Interagency	Total	Base	Interagency	Total
350	700	1,050	350	643	993

* Budget for tools and methodologies development only. Fish and wildlife participation in marine and fresh water resource planning and evaluation was in the $8 million range during FY 1976.

CONCLUSIONS

The Fish and Wildlife Service has actively participated in water resource planning for many years and is now identifying, evaluating, and attempting to solve energy related problems which threaten fish, wildlife, and environmental values. This is a new thrust for the Service with a major goal of providing information to appropriate decisionmakers in a useful form and timely manner which will ensure that fish and wildlife values are carefully considered.

In the freshwater efforts area the data needed relates principally to the determination of the water quality and quantity that must be preserved in existing natural systems to maintain viable habitats for fish and wildlife. Improved methodologies and new approaches are required and these are being developed by the Service's freshwater energy activities. Success of the entire effort depends on interagency and State cooperation. Interagency supplemental funds are permitting an increased rate of methodology development. The program is expected to result in a greater understanding of the tradeoffs between alternatives and accelerated energy development decisions in non-sensitive areas.

USDA RESEARCH AND DEVELOPMENT ON EFFECTS OF ENERGY PRODUCTION AND USE ON FRESHWATER RESOURCES

Harry E. Brown
USDA - Forest Service
Washington, D. C.

INTRODUCTION

Because agriculture is one of the biggest users of water in the United States, it is vitally concerned with the increasing impacts that energy-related activities are having on the Nation's water resources. U. S. Department of Agriculture agencies conducting programs directly concerned with management of agricultural and forest lands must bear responsibility for maintaining the quality and availability of water resources in the face of these impacts. Of particular concern are pollutants resulting from fuel extraction and diversion of water from agricultural to energy uses (8).

The purpose of this paper is to provide a brief description of the overall energy research program of USDA, with particular emphasis on research dealing with effects of fuel extraction on water resources.

The U. S. Water Resources Council and National Commission on Materials Policy have identified some of the potential impacts resulting from energy development. These include sediments associated with mining, thermal wastes, acid mine drainage, pollutants resulting from coal washing, and concentration of pollutants and decreased streamflow resulting from increased consumptive use (5,9). Energy-related impacts on water quality may also result from energy conservation practices used in the production of food, fiber, and forest products. Another major concern is the possible impact on agricultural production of transfers of water from agricultural to energy uses.

On the plus side, there are often positive effects on water resources resulting from energy development. For example, well planned water impoundments in strip mined areas can enhance recreation and wildlife values.

Water rights, as well as numerous Federal statutes enacted over the years, affect control and development of surface water resources of the United States. The 1872 Mining Law and 1920 Mineral Leasing Law, along with the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500) are examples of pertinent statutes. PL 92-500 is particularly significant because it requires control of pollution from mining activities. Among other things, it requires that guidelines be provided -- "for identifying and evaluating the nature and extent of nonpoint sources of pollutants and processes, procedures, and methods to control pollution resulting from -- mining activities, including runoff and siltation from new, currently operating, and abandoned surface and underground mines."

USDA ENERGY RESEARCH PROGRAM

The U. S. Department of Agriculture has initiated an energy research program of broad scope that is addressing water pollution as well as other energy-related problems. Its overall goals are to conserve scarce fuel supplies and maintain environmental values and quality of rural living while expanding agricultural and forestry production to meet growing U. S. and rural needs.

The following program objectives are identified:

A. Conservation -- Increase the efficiency of energy use in the production, processing, marketing, and utilization of agricultural and forestry products and develop systems less dependent on petroleum and natural gas. This includes research in environmental effects of energy conservation technologies.

B. Bioconversion and photochemical -- Develop technology for biomass production and for conversion of agricultural and forestry products and wastes into useable energy fuels, petrochemical substitutes, and other products.

C. Nonfuel sources -- Develop technology for the utilization of solar, wind, and geothermal energy in agriculture, forestry, and rural development.

D. Reclamation and environment -- Develop technology to reclaim mined lands and to protect and enhance the environment and quality of rural living as affected by energy shortages and energy development.

E. Resources -- Develop technology to assure supplies of plant nutrients, land, water, and other vital inputs as they are influenced by energy supply.

Of these objectives, only "Conservation" and "Reclamation and Environment" are dealt with further in this paper because of their important implication for water resources.

The USDA agencies involved in the program are those that conduct programs directly concerned with the management of soil, water, plants, and animals on rural private and public lands. They include the Agricultural Research Service, Cooperative State Research Service, Economic Research Service, Extension Service, Forest Service, and the Soil Conservation Service. Limited additional funding in support of the program is made available by the Bureau of Mines, Environmental Protection Agency, Energy Research and Development Administration, Federal Energy Administration, and the National Science Foundation.

The U. S. Water Resources Council (10) describes the water and energy-related programs of three USDA agencies in Table 1. In addition, the Cooperative State Research Service is involved in water and energy research through the State Agricultural Experiment Stations, Colleges of Forestry, the 1890 Colleges of Agriculture, and Tuskegee Institute. The Economic Research Service is involved through socio-economic research aimed at achieving a proper balance between agricultural production and the use and quality of natural resources.

Within the context of this overall energy research program and relevant agency responsibilities, we can examine some specific examples of USDA studies dealing with effects of energy-related activities on freshwater. These particular studies are concerned with effects of energy conservation practices and mining on freshwater from Sections A and D of the USDA Energy Research Program.

Studies of Effects of Energy Conservation Practices on Freshwater

1. Effects on freshwater of energy-efficient techniques for establishing forest trees. Establishment techniques such as prescribed fire could result in substantial energy savings compared with use of heavy machinery. However, more needs to be known about effects of alternative techniques on water quality.

2. Effects on freshwater of energy-efficient cutting systems in major forest types. New research will establish the most energy-efficient cutting practices consistent with acceptable quality of stream runoff from harvested watersheds.

3. Effects on water quality of energy-efficient timber harvesting practices and logging road designs.

4. Effects of energy-efficient nutrient management practices on water quality. Practices aimed at reducing the need for energy intensive fertilizers could have favorable implications in terms of water quality. For example, if nitrogen fixing plants are developed to replace nitrogen fertilizer, there could be a considerable reduction in nutrient pollution of runoff water. On the other hand, water quality could be affected adversely by sewage wastes applied to the land as an energy conservation measure or by increased use of pesticides as substitutes for more energy-intensive tillage practices.

Studies of Mined Land Reclamation

A major USDA reclamation program has been initiated with support from the Environmental Protection Agency and other Federal agencies. Portions of this program are described in accompanying papers by David Ward, Howard Heggestad, and John Schaub, so only the parts dealing with water resources will be touched on here. Water-related objectives of the reclamation program are as follows:

1. Effects of coal and oil shale extraction on freshwater.
    a. Develop baseline information for use in evaluating potential effects of energy technologies on freshwater ecosystems.
    b. Determine the immediate and long term effects and biological fate of energy related pollutants on freshwater resources and ecosystems and evaluate ways to minimize these effects.
    c. Determine the immediate and long term nonpollutant effects of energy technologies on freshwater resources and ecosystems and evaluate ways to minimize these effects.
2. Integrated assessments.
    a. Estimate social, economic, and cultural consequences of alternative energy production and pollution control technologies. Included here are (1) evaluations of economic effects of energy-related activities on demand for water and economic life of aquifers, (2) development of implications for interregional transfers of water, and (3) evaluation of effects of increased water demand on agricultural industries, environmental quality, and rural resource use.
3. Technologies for controlling effects of mining and related activities on agricultural, forest, and range lands.

Some examples of studies of freshwater effects follow:

1. Baseline studies. Studies are being implemented to describe premining surface and subsurface water resources on agricultural and forest lands in terms of quantity and quality. A Technical Information Service, SEAM INFO, is being developed to alert those needing information

on reclamation of surface mined lands to new documents and their sources and to refer them to existing data bases and services.

2. Effects and biological fate of energy-related pollutants on freshwater resources. In a study at Rapid City, South Dakota, the quality of water in water bodies in strip mined areas is being investigated as it relates to the habitat for aquatic organisms and wildlife species associated with these water bodies. This study will utilize existing information to establish water quality limits and guidelines. It will also provide information needed for design and management of water impoundments in strip mined areas in the Northern Great Plains. Another study will assess the effects of mining-related transportation systems on water resources. Others are directed at determining the movement in water channels of pollutants associated with the mining activities.

3. Nonpollutant effects of energy technologies on freshwater resources and ecosystems. Studies are being conducted to determine effects of mining activities on surface runoff and runoff-infiltration relationships on mine spoils. Investigations are being made of mining techniques that will utilize minimum quantities of water. Included in all the above is development of modelling technologies for predicting hydrologic responses to mining.

4. Control technology studies. Technologies are being evolved for ameliorating adverse effects of mining and related activities on freshwater resources. Examples include: (1) procedures for characterizing overburden and associated ground water in advance of mining, (2) procedures for revegetating mine spoils in such a way as to stabilize the spoils and prevent erosion and sedimentation of runoff waters, (3) designs of interceptor ditches, structures, and other methods of controlling runoff and sedimentation, and (4) evaluation of various techniques and equipment for treating polluted water from mined lands.

RESULTS OF ONGOING RESEARCH

Following are some recent results of investigations of effects on freshwater of surface mining:

1. Effects of strip mining on small stream fishes in east-central Kentucky were reported by Branson and Batch (1). Continued siltation from strip mined operations in two streams prevented the recovery of fish populations. Fish were forced downstream and several species are now absent. During the 2 year period of this study the monthly low and high turbidity readings averaged 95 and 544 Jackson Turbidity Units, respectively.

2. Measurements of sediment accumulation in debris basins below surface mined lands in eastern Kentucky showed highest sediment yield during the first 6 months after mining (3). The erosion rate diminished to fairly low levels within 3 years. Methods of mining and handling spoil affected sediment yield as did the speed with which vegetative cover was established. The lower sediment yields appeared to be associated with "head-of-the-hollow" fills which caused less exposed surface area on steep slopes. Ridge tops removed after making the initial cuts and hollow fills resulted in relatively flat areas less subject to erosion. Vegetation that had been removed and windrowed across the slope along the toe of spoils trapped much of the sediment. Seeding to a mixture of grasses and legumes soon after disturbance produced a quick cover of protective vegetation.

3. Chemical pollution of streams may take place following mining if toxic overburden is left on the surface where it is exposed to rapid erosion and leaching (2). By burying these materials and conducting other reclamation practices these effects can be minimized. On four study watersheds in West Virginia where mining and reclamation were conducted in accordance with current laws and regulations adverse effects on water quality were minimal. Reclamation practices here included burial of suspected toxic material, control of slope length, bench regrading, and revegetation (6).

4. Evaluation of overburden material before the start of mining is suggested as the most reliable means of predicting spoil quality and devising mining and reclamation plans. This can best be accomplished by core drilling the proposed area and making chemical analyses of the cores. Color, pyrite, and pH are field guides used to determine the potential toxicity of exposed overburden strata (4).

5. An exploratory study in the Northern Great Plains was aimed at determing how runoff from spoil materials is affected by surface treatments (7). Without treatment nearly all of the precipitation left the plot as runoff; whereas with

various combinations of treatments, runoff was reduced to as little as one-fourth of the precipitation. The treatments included various combinations of gypsum, sulphur, straw, and topsoil. This study provides an indication of the degree of on-site water conservation that can be achieved by runoff control practices.

PROJECTED PROGRAM ACTIVITIES

The following national energy goals provide guidance for future environmental research:

1. Protect and enhance the general health, safety, welfare, and environment related to energy research and development.
2. Seek means for the development of environmentally safe and economical energy programs.
3. Expand the domestic supply of economically recoverable energy-producing raw materials.
4. Perform essential basic and supporting research related to energy extraction.

To meet these goals, major emphasis will be directed to research aimed at ameliorating effects of fuel extraction on freshwater resources. This will require that a better understanding be developed of the physical and biological process affected by mining. Assisted by this knowledge, techniques can be devised for accurately predicting environmental impacts and choosing the most cost-effective measures for reclamation of land and protection of water resources.

Near term (1985) objectives of reclamation research aimed at these problems include determination of the potential physical, biological, and socio-economical impacts of mining operations and resultant airborne pollutants on important agricultural and forest ecosystems, particularly aquatic systems. Assessments of these impacts are needed for the timely formulation and implementation of policies and programs for extracting fuels in a manner to maintain a quality environment.

Midterm (2000) objectives are to evaluate existing and emerging technological and reclamation control methods and to determine the needs and means for further development and refinement of technology and methodology for protecting and improving environmental resources and values.

An example of an immediate problem requiring intensified research is that of sodic mine spoils in the Northern Great Plains. The generally high exchangeable sodium content of the Fort Union Shale and Coal Formation causes spoil materials from the deeper shale beds in this region to present serious revegetation problems. A critical need exists to preplan mining operations and manage the spoil areas in such a way as to avoid saline runoff and erosion. Possible effects of salt pollution on downstream areas and communities can be very important in determining the feasibility of large scale coal mining. The problem is compounded by the fact that this is generally a water-scarce area and diversions of water to coal processing and transportation uses will mean higher water prices and lower availability of water for agriculture and other purposes.

A Federal role is essential in the accomplishment of the objectives that have been described. Energy development is a national goal and the impacts caused by energy development are also of national importance. They cut across many regions and sectors of the economy, and alternatives and tradeoffs must be evaluated within a national context. Without Federal research and development it will not be possible to structure and implement laws that are consistent with national goals.

Solutions to energy-related environmental problems can be found through a comprehensive R&D program undertaken on a national scale. The research organizations of the USDA, along with cooperating universities, are seeking these solutions.

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TABLE 1
Inventory of current agency programs related to water required for energy locations, development, transport, processing, or production (10).

AGENCY	NAME OF ACTIVITY	PURPOSE	LOCATION	AMOUNT OF WATER AND ENERGY	RESULTS EXPECTED OR ACCOMPLISHED
Soil Conservation Service	**1. Snow survey and water supply forecasting.**	**Predict river flows.**	**11 Western States and Alaska.**	**Forecast water supply for all major streams, including hydroplant locations.**	**Optimize reservoir operations.**
	2. Soil and water conservation.	**Preserve water quality by control of erosion and runoff in disturbed areas.**	Nationwide.	Not estimated.	**4.4 million acres have been disturbed in the U.S. by surface mining. Over 1 million acres of mined land have been reclaimed in 2,000 soil conservation districts.**
	3. Resource conservation and development projects and small watershed projects.	Water storage for multiple uses and conservation measures for water supply and erosion control.	Nationwide.	Not estimated.	974 RC&D projects are authorized for 615 million acres, including 430,000 acres in 682 existing projects. Over 1,000 small watershed projects have been approved with 392 which have structural measures completed.
Agricultural Research Service	1. Watershed hydrology research.	Predict impact of land management and water control programs on runoff and improve snowmelt forecasts.	Nationwide	Not estimated.	Information for planning.
	2. Strip mine revegetation research.	Reclamation of spoil material.	Md., Va., W.Va., and N.D.	Not estimated.	Work in Eastern States covers acid wastes and Dakota study involves alkaline material in lignite areas.
Forest Service	1. Surface environment and mining. (SEAM)	Maintain environmental quality in meeting mineral requirements by exploring alternatives, analyzing impacts, and demonstration areas.	Initially in western large scale mining areas.	Not determined.	Reduce delays in leasing, improve technology of rehabilitating mined areas, maintain environmental stewardship.
	2. Management of forested watersheds and grasslands.	Multiple uses.	Nationwide.	Forested areas provide over 60 percent of total water yield and maintain water quality. 187 million acres of National Forests yield 390 million AF of water aiding power generation and transport.	Maintain water supply and quality.
	3. Water research.	Improve water yield, stabilize erosion, improve streamflow timing.	Nationwide.	Not determined.	Information for public use.

Freshwater Ecological Effects

H. R. Hickey and P. A. Krenkel
Tennessee Valley Authority
Chattanooga, Tennessee

INTRODUCTION

In the nineteenth century, sanitary engineering, the techniques of managing water supply and waste treatment, became the first recognized professional environmental discipline. By comparison, the investigation of more subtle aquatic ecological impacts of thermal and chemical effluents is a fairly recent development in environmental science and engineering. The relationships between temperature, dissolved oxygen, natural reaeration, metals concentration, and aquatic life require more investigation than had been necessary to design water supply and waste treatment plants. The "environmental statement" process revealed the need for a reliable method for predicting and measuring impacts on aquatic ecosystems.

TVA's research efforts in this area include several tasks related to impacts of energy technologies on aquatic ecosystems, effects of strip and surface mining and reclamation on water quality and ecology, and one minor project to evaluate the role of strip mine pools in the production of disease-bearing arthropods.

For possible use in the exchange of information or coordination, the names of principal investigators, research investigators, and responsible administrators are included after the title of each task.

DISCUSSION

1. Consolidation of Baseline Information, Development of Methodology, and Investigation of Thermal Impacts on Freshwater Shellfish, Insects, and Other Biota--B. G. Isom, R. H. Brooks, W. R. Nicholas

A. Information Systems Development--John S. Crossman

The immediate short-term objective of this task is the development of a data base system in which biological data can be stored and retrieved for recurring uses associated with ongoing research and monitoring programs for a large electrical utility. With the development and implementation of this system, it will be possible to review biological data that has been collected in the vicinity of eight coal-fired power generating plants for information on the basic structure and function of biological communities subjected to thermal discharges in a semi-riverine environment.

After the review of the previously collected data, representative benthic populations will be selected for further study under both field and laboratory conditions. This long-term portion of the project will utilize bench scale biological models that can be manipulated to simulate environmental conditions associated with energy technologies. The use of laboratory microcosms, supplemented by field measurements, will provide basic data on the biological productivity of freshwater communities, growth rates of important representative species under different environmental conditions, relative abundance of important species, and the response of different species to toxic materials. The data generated by these studies will be utilized to verify existing ecosystem models or their refinement for use within the Tennessee Valley. These models will also be applicable to similar ecosystems throughout Appalachia and the Southeast.

Progress: In October 1975, a meeting was held in Cincinnati to review the design specifications for the Environmental Protection Agency's proposed BIO-STORET data base system. This was followed by a review of the structure and content of the parameter list to be included in the data base, along with proposed recommendations. These recommendations are now in the process of being incorporated into a final design package which will be used in the implementation of the program.

With the development of a data storage and retrieval system, a data reduction and analyses package has been obtained. This package is the NTSYS - Numerical Computer Taxonomy Programs, which contains the software capabilities to undertake a comprehensive review of the previously collected biological data using a variety of cluster and factor analyses, distance and association coefficient matrices, and correlation analyses. These programs are currently being adapted and tested for use within the Tennessee Valley Authority's system.

Progress on the development of laboratory simulations of streams and reservoirs and investigation of ecosystem modeling are in the literature review and evaluation phase.

B. Acute Thermal Effects - Aquatic Insects--R. D. Urban, K. Tennessen, J. L. Miller

The aquatic insect fauna of any freshwater ecosystem constitutes a vital link in the transfer of energy via the food web. The maintenance of a diverse and abundant population of aquatic insects helps establish a resilient trophic structure. Increasing demand for electrical energy creates a corresponding increase in the need for condenser cooling water. The increased use of freshwater for cooling purposes in turn necessitates an increase in the thermal load imposed upon the receiving water body. At this point questions arise as to the ability of the aquatic flora and fauna to tolerate this added perturbation. The goal of this research task is to determine the threshold of thermal tolerance for several aquatic insects found in the reservoirs of the Tennessee and Cumberland River Watersheds, typical of Appalachia and the Southeast.

Objectives: In response to Public Law 92-500, TVA initiated biological studies in June 1973 to assess the effects of thermal effluents from fossil-fueled steam-electric stations. In the course of these evaluations a basic question continued to arise: What level of thermal enrichment can a water body be subjected to before deleterious effects to the various life cycle stages of the aquatic biota occurs? While some information is available in the literature, in general latitudinally comparable data or data concerning the desired species are not available. In addition, the data seldom address different seasonal thermal regimes for the various life cycle stages. A third area of concern for which there is a severe lack of information concerns plume entrainment of insect fauna in multipurpose reservoirs. Hence, it is the objective of this task to provide pertinent thermal tolerance data for a burrowing mayfly and selected chironomid species found in the TVA reservoirs.

Specific Goals: The objectives will be achieved using both field and laboratory studies. Emergence traps will be utilized to compare emergence success between areas influenced by thermal plumes versus control reaches. Gamete development, egg and sperm viability, egg hatchability, etc., will be compared between the two naturally emerging groups. In addition, test individuals in different life cycle stages will be placed in a flotation device and floated in the thermal plume until the temperature is degraded to a ΔT of 2°C. The survival rate will be determined and surviving members will be reared to maturity to assess the impact of the thermal stress upon the reproductive potential of these organisms.

In the laboratory, organisms in various life cycle stages will be exposed to a series of ΔT's in order to determine the temperature threshold for each life cycle stage. In addition, growth studies will be conducted on those individuals that survived the various thermal shocks. This will allow the investigators to assess the effects of various levels of thermal shock upon the growth rate of individual organisms as well as the effect upon the reproductive potential and success of the test organisms.

C. Biochemical Methodology, Aquatic Thermal Impacts--S. A. Murray, C. Burton

New and improved biochemical diagnostic procedures will be utilized for assessing environmental effects resulting from energy-related thermal stress.

Specific tasks include application or development of techniques of extracting body fluids and plant pigments that can be utilized to monitor thermal stress in the aquatic environment.

Existing data from ongoing monitoring programs at fossil-fueled and nuclear plants will be used to select the experimental biota.

Progress: Development of primary facilities for culture of experimental animals and plants has been essentially completed. Most facilities were developed for previous research and monitoring activities.

A literature review on biochemical methodologies has been initiated. The review to date includes information from the National Technical Information Service, Smithsonian Science Information Exchange, and our own resources.

Status: Project activity is proceeding as scheduled. However, delay in the finalization of the TVA/EPA contract and delays in transfer of funds from EPA to TVA may require the submission of revised TVA milestone completion dates. We anticipate that the final completion report to EPA will be made on schedule.

D. Biomonitoring; Mollusks; and Others--B. G. Isom, C. H. Gooch

The objective of this research task is to quantify the role of bioaccumulation in cycling of selected trace elements (metals and radionuclides) released to aquatic ecosystems by the thermal component of coal combustion and nuclear steam-electric stations. A primary result of the research will be methodologies for implementation and evaluation of bioaccumulation (biomagnification) studies.

For the past few years, TVA has conducted studies on the distribution of mollusk species in those reservoirs near TVA coal-fired steam plants and at proposed and operational nuclear plant sites. More information is needed on the use of mussels and other biota to monitor metals, nuclides, and organic chemical in the environment.

We have considerable background literature on toxicity of power plant chemicals to aquatic life and other miscellaneous bioaccumulation literature. In addition, an extensive survey has just been concluded of the postimpoundment overbank habitats and areas immediately below the Tennessee River mainstream dams. This survey revealed the types and quanties of mollusks species available for study of bioaccumulation near power plants. A broad selection of mussel tissues and extrapallial fluid samples were collected for use in determining background levels of important trace element and nuclide species.

Data from preliminary analyses of selected tissues indicate bioaccumulation of copper, zinc, cadmium, lead, and bismuth. Initially, this research will be restricted to evaluating bioaccumulation and analysis of the trace metals copper, zinc, and chromium and the nuclides strontium^{90}, cesium^{137}, cobalt^{60}, and gross nuclide accumulation.

Trace metals research will be conducted at the coal-fired Bull Run Steam Plant on the Clinch River and at the Browns Ferry Nuclear Plant on the Tennessee River.

TVA and Oak Ridge National Laboratory (ORNL) have coordinated studies scheduled for the Bull Run Steam Plant. ORNL studies will evaluate the chemical elements from the ash ponds and the biogeochemical cycling of these elements. The TVA studies on trace metal accumulation will be restricted to the thermal system. Studies at Browns Ferry will cover total plant effects since the diffusers there discharge both thermal and chemical effluents.

Status: The literature review for this project is nearing completion. This review included searches conducted by the National Technical Information Service, the Smithsonian Science Information Exchange, and the TVA library.

The project is proceeding as planned. A TVA milestone report on literature and methodology will be completed on schedule. It is anticipated that other milestones will be achieved within the time frames outlined in the subagreement.

E. Evaluate Water Intakes - Zooplankton Entrainment--R. D. Urban, D. L. Dycus

Zooplankton represents a critical link in the aquatic food web, for it is this group of microcrustaceans and rotifers that convert plant materials (algae) into animal protein. As such, this group becomes an indispensible food resource for larval and some adult fishes as well as many macroinvertebrates. An activity that utilizes raw water may disrupt the food web dynamics of the source body of water by reducing the number of zooplankters available for energy transformation and consumption. To avoid unnecessary disruption of the food web, various intake structures have been proposed for industries that use large volumes of raw cooling water.

TVA has for some time utilized several different intake designs at its twelve fossil-fueled steam-electric stations to create an effective heat transfer ratio in the condenser cooling systems. A possible ancillary benefit derived from the various intake structures at TVA fossil-fueled steam-electric stations may be a reduction in adverse biotic effects. The primary goal of this research task is to evaluate the effectiveness of these various intake structures in curtailing the entrainment of the planktonic food resources within the condenser cooling system. An additional goal will be to develop criteria that can be utilized in both siting and designing of new intake structures.

Objectives: In response to Public Law 92-500, TVA initiated studies of zooplankton condenser passage to assess the effects of both intake design and condenser cooling system entrainment upon the zooplankton assemblage near TVA fossil-fueled steam-electric stations. To fully utilize these data additional information concerning the spatial distribution of the zooplankton within the area of the various intake structures as well as some basic hydrological data (e.g., current direction and velocity) is needed. The collection of these additional data will aid in the evaluation of the various intake designs that limit entrainment of planktonic organisms.

Specific Goals: The objectives will be achieved using both field and laboratory studies. Horizontal and vertical distribution of the zooplankton will be investigated as a water mass approaches the intake zone, within the intake zone, and downstream of the intake zone. It should be emphasized that when possible the same water mass will be sampled at each of the defined transects. Vertical tows with one-half meter plankton nets equipped with a digital flowmeter suspended in the throat of each net will be used to document horizontal distribution. A plankton pump will permit the investigators to describe the vertical distribution of the zooplankton assemblage. The sample will be preserved and returned to the laboratory for standing crop and biomass analyses.

Laboratory studies will investigate avoidance behavior of various zooplankters. Several intake design alternatives will be utilized to document changes in zooplankton distribution within the water column (i.e., bubble screens, pressure differences that result from different shapes and types of objects being placed in the water column, and variable light intensity).

2. Strip Mine Drainage Water Quality with Emphasis on Toxic Substances--Doye B. Cox, Roger P. Betson, R. J. Ruane, J. Crossman, W. C. Barr, W. R. Nicholas

The goal of this project is to demonstrate methodologies for predicting the impact of surface mine reclamation strategies on a downstream fisheries resource with the strategies based on the characteristics of the site to be mined. Objectives necessary to accomplish this goal are: (1) to identify the occurrence and significance of major and minor chemical elements and compounds in strip mined areas; (2) to calibrate existing regionalized hydrologic models using data from surface mined watersheds with several types of reclamation; (3) to develop or extend nonpoint source water quality models in order to predict the natural-area environmental loadings of important water quality constituents (4) to relate the transport of significant elements and compounds and water quality constituents to the hydrology of small strip mined watersheds; (5) to investigate the relationship between the chemical composition of strip mine overburden and the downstream transport of important constituents that exceed natural-area environmental levels; (6) to evaluate the effects of "conventional treatment" (i.e., liming, limestone addition, sludge application, etc.) on acid production and chemical mobilization and transport; (7) to investigate the relationship between transport of important constituents and the fishery resource. The work will consist of laboratory and field studies conducted by TVA's Water Quality and Ecology Branch, coordinating with the Division of Forestry, Fisheries, and Wildlife Development and the Division of Water Management.

Progress: Early activities have concentrated on coordination of agencies or groups involved in strip mine research in the Tennessee Valley area. On August 28, 1975, a meeting in Nashville was chaired by Stanley Sauer, District Chief, U.S. Geological Survey (USGS) with representatives of the Soil Conservation Service (SCS), Corps of Engineers (CE), USGS, and TVA staff attending.

A second meeting was held on September 17, 1975, in which these agencies and Tennessee State Planning Office (TSPO), Department of Conservation--Office of the Commissioner and the Water Resources and Surface Mining Divisions, Tennessee Wildlife Resources Agency (TWRA), University of Tennessee at Knoxville (UT), and Oak Ridge National Laboratories (ORNL) participated. The purpose of this meeting was to exchange information on existing or planned hydrologic data collection programs in order to avoid duplication of effort. An interagency committee will be established to exchange information on time frames for data collection and to establish procedures for formulating and sharing information collected. The USGS will take the initiative in establishing the committee with the aid of the TSPO.

TVA has agreed to partially fund The University of Tennessee's watershed strip-mine project in the New River Basin. The Special Projects Staff will provide monies to the USGS for data collection and the installation or upgrading of rainfall and streamflow gaging stations on The University of Tennessee's study areas. In return The University of Tennessee will provide hydrologic and water quality data that is being collected in the six basins (3 mines, 3 virgin) under study. These data are collected on a weekly basis and will be used in model development and calibration. In addition, data from adjacent areas in the New River Basin will be made available from the USGS and Corps of Engineers for model development and calibration.

Much of the reconnaissance survey data that had been planned in the New River Basin is being supplied by the USGS, and the Corps of Engineers. Amax Coal Company and The University of Tennessee have supplied water quality and flow data from area mined sites in the Piney Creek area of Southeastern Tennessee. Further reconnaissance sampling in the New River Basin will be conducted as needed.

A study site on Crooked Creek near Jamestown, Tennessee, was selected that will enable characterization of strip mine drainage water quality from an area-mined site in which the miner has employed acceptable reclamation procedures. We plan to monitor water quality at two sites in the basin and at an additional control site. The Special Projects Staff will provide monies to the USGS for installation and maintenance of rainfall and streamflow gaging stations at these three sites.

A comprehensive literature review is of trace metals mobilization and transport and strip mining water quality, hydrology, and biological effects is underway. In addition literature dealing with kinetics of acid drainage formation has been searched extensively. Other agencies and individuals involved in research in these areas have been contacted.

A detailed workplan with task, expenditure, and man-hour schedules is nearing completion.

Status: Work is progressing at a rate necessary for the achievement of project goals. Water quality sampling should be underway on the area-mined site by January 1976. Biological sampling at a site affected by mine drainage should begin during the first quarter of calender year 1976.

3. Production of Arthropod Pests and Vectors in Strip Mine Pools--Eugene Pickard, Joseph Cooney

The objective of this study is to survey and determine types of aquatic arthropod pests, mainly mosquitoes, that breed in strip mine pools, and the extent to which these breeding sites could annoy surrounding communities. Physical and chemical parameters of pools will be correlated with their age and successional stage.

A preliminary reconnaissance was made of the strip mine areas near Brilliant and Stevenson, Alabama, to delineate and rank candidate study sites. An inspection was made with the Taylor and Son Company reclamation officer to establish age classification of strip mine pools in the Brilliant, Alabama, area. Test pools have been selected in the vicinity of Gold Mine, Alabama (Marion County), and marked in the field for study. Photographs have been made of several pools for use in establishing vegetation baselines.

Study pools have been selected on the basis of age as follows: newly formed pools (less than 1-year-old), 5-year-old pools, and pools 10 years old or older. Three pools in each age class have been selected for study.

Physical characteristics that will be recorded for the pools are water depth, margin abruptness, soil type and texture, and water source. A reference point will be established from which sequential photographs will be made.

Measurements of temperature, dissolved oxygen, pH, and salinity will be taken from the water at established sampling points in each study pool.

An initial survey will determine the presence of aquatic plant species and their percentage composition in the pools. Inventories of vegetation will be conducted annually to provide quantitative estimates of the changes in the woody and herbaceous vegetation.

Immature stages of mosquitoes will be sampled with the standard white enamel dipper. The floodwater or rainpool group of mosquitoes will be determined by collecting and processing soil samples from likely floodwater habitats. Other aquatic insects will be sampled with seines and botton sampling devices. Adult insects will be collected by a combination of methods, including light traps, malaise traps, sweep nets, and biting collections.

Should significant mosquito populations develop in coal surface mined pools, various methods of control will be investigated. Naturalistic, or biological methods, such as the introduction of larvivorous fish, mosquito parasites, or certain species of aquatic plants such as Lemna and Taxodium that appear to limit mosquito production, will first be investigated, then chemical methods will be studied.

The effect of reclamation activities as a means of creating, destroying or mitigating mosquito productivity will be evaluated.

4. Ecological Recovery After Reclamation of Toxic Spoils Left by Coal Surface Mining--W. M. Seawell, J. B. Maddox, T. G. Zarger

The objective of this study is to determine the effectiveness of land stabilization treatments toward restoring a damaged ecosystem. The study involves a problem watershed in which 400 acres of forested land were disturbed by coal surface mining in the early 1970's. Unsuccessful reclamation efforts resulted in adverse environmental impacts within an 11-square-mile watershed that includes a city water supply reservoir. Project objectives will be accomplished by applying intensive remedial land treatments and evaluating their effectiveness by measuring the degree of recovery of the affected terrestrial and aquatic ecosystems.

Repeated attempts by the mine operator to revegetate the spoils by standard treatments have resulted in only 25 percent of the mined land surface being stabilized. Erosion from barren bench and outslope areas is contributing seriously to offsite damage that includes deterioration of receiving stream quality and siltation of the reservoir. The problem is one of highly toxic spoils--an acid problem of geochemical origin associated with a specific coal seam found extensively in east Tennessee.

Previous studies on ecological recovery of surface mines have not included monitoring of such a seriously impacted watershed. Results should provide new and significant information in the evaluation and correction of problems associated with future mining of this particular coal seam.

Before underwriting the cost of this intensive remedial land treatment, TVA considered many possible remedies, including evaluation of results from a series of investigations conducted between 1970 and early 1973. Treatments were sought that would provide the most effective way to stabilize the area without accelerating the rate of reservoir siltation.

Funds for monitoring the recovery of the affected terrestrial and aquatic ecosystems are provided by EPA pass-through monies. Existing conditions will be measured and evaluated prior to restorative treatments. Monitoring will continue through treatment and thereafter on a more limited basis so long as significant recovery is noted. Environmental data collected during the period of mining and reclamation (early 1970's) will serve as initial baseline study data.

Progress: Following preparation of a summary workplan in July 1975, collection of data was begun on both terrestrial and aquatic systems. Individual workplans covering two major investigative phases (terrestrial flora and stream fauna) have been prepared. These field investigations record the present condition of the mine site and water quality in receiving streams.

Terrestrial--The vegetation survey was conducted prior to the scheduled October treatment of the mined area. This fall one-third of the affected acreage was treated with agricultural limestone at the rate of 10 tons per acre, seeded with a winter annual grass, fertilized, and disked. The survey records types and amounts of vegetation, both natural and that resulting from previous revegetation efforts. Data collected includes: (1) types of trees and shrubs growing on the site, their size and abundance, and (2) types of grasses and herbaceous species, their height and the percentage of ground cover for each species. Survey of mine spoil conditions are also under way. This data will serve as a basis for measuring the rate of recovery during the monitoring program, as the same area is subsequently surveyed after treatment.

Aquatic--Four sampling stations have been established on the main stem of Ollis Creek. Additional stations have been located on Laurel Creek, Yellow Creek, Thompson Creek, and an unnamed stream, all of which are tributaries of Ollis Creek. One sample station has also been located on No Business Creek, a similar nearby watershed which is virtually unaffected by surface or deep mines.

All stations (except No Business Creek) have been sampled monthly for four months for bottom fauna (four 1-square-foot Surber samples per station). Identification and tabulation of the samples is under way.

One set of artifical substrate samplers (rubble-filled wire baskets--four per station) have been placed and collected. Future plans call for placing the samplers at each station and removing and replacing the samplers every two months.

At all stations 100-foot lengths of stream have been sampled for fish populations by electrofishing. Future plans call for sampling these stations semiannually.

Water Quality--Water quality parameters have been measured four times at each station in Ollis Creek and its tributaries. Analyses were performed for dissolved oxygen, turbidity, suspended solids, conductivity, pH, alkalinity, total acidity, sulfates, manganese, and iron.

Status: Project activities are proceeding on schedule. At this time, no milestone dates are expected to need revision.

The EPA Research Program on the Freshwater Ecological Effects of Energy Development and Use

J. David Yount, Ph.D.
Office of Health and Ecological Effects, EPA
Washington, D.C.

INTRODUCTION

Although the long term energy needs of the U.S. depend on the development of energy sources other than fossil fuels, it is evident that at least for the remainder of this century we will continue to be heavily dependent upon fossil fuels. Of these coal provides the largest and most rapidly utilizable energy source: hence the impacts resulting from greatly intensified coal mining, transportation, storage, and conversion to energy will be the most immediate. Oil use will continue, with environmental impacts resulting from development of new sources such as those in Alaska.

Of less immediate importance is the potential large-scale utilization of oil shale formations. New techniques of coal processing, such as liquification and gasification, appear to be an economically feasible method of converting coal to a relatively clean fuel. What is not yet apparent however, is the fate of the contaminants removed from the coal in these processes.(1)

TECHNICAL DISCUSSION

Although the Environmental Effects section of this symposium is broadly subdivided for convenience into marine, freshwater and terrestrial effects, it is not possible, at least in this case, to completely separate the freshwater aspects from the terrestrial. In fact the conceptual scheme around which these studies were organized can best be described as that of a watershed ecosystem, in which the primary transport mechanism of interest is the terrestrial hydrologic cycle. Thus, although the aquatic aspects are emphasized, precipitation (wet and dry), soil conditions and effects, and ground water flows are also important aspects.

Because of the regulatory problems implied by the above energy source development and utilization EPA recognized the need for information on the effects of these activities on watershed ecosystems. Therefore, two areas were chosen for initial primary emphasis: the effects of oil transport by pipeline from Arctic oil fields; and the mining, transportation, storage, and energy conversion of coal. In anticipation of potential future development, smaller programs were initiated on oil shale and on coal conversion.

EPA's Duluth, Minnesota Environmental Research Laboratory (ERL) developed research projects with five universities to explore the freshwater and watershed environmental degradation which results from coal and oil shale utilization. The projects were designed to produce data which could be modeled in such a manner that predictions could be made which would aid in site selection for future energy source and conversion facilities, so as to result in the least possible environmental degradation.

One project, conducted jointly by the Colorado State University Natural Resource Ecology Laboratory and the Montana State University Fisheries Bioassay Laboratory, concerns the toxic effects on aquatic biota and the effects on aquatic ecosystems resulting from coal and oil shale development in Montana and Colorado.

Another project in the Duluth ERL program involves transportation, off-loading, and subsequent reloading of coal at a port facility. In March 1975 the Burlington Northern Railroad started construction of a $50 million dock facility located on Lake Superior at Superior, Wisconsin. This facility will be used to load large lake freighters with Western coal for eventual utilization at electrical generating plants on the lower Great Lakes. Initial annual tonnage will be in excess of 5 million tons. Studies here include bottom fauna and algal stimulation or inhibition in the loading area by the leachate from coal stored and subjected to atmospheric conditions. Pre- and post-operational research is being conducted by the University of Minnesota, Duluth and the University of Wisconsin, Superior to assist in development and location of similar future operations so as to produce the least possible environmental damage.

The final project in the Duluth ERL program is funded jointly with the Corvallis, Oregon ERL. This is a complete environmental study, by the University of Wisconsin (Madison) Institute for Environmental Studies, of a coal-fired electric power generating station in a wetland area.

All of these studies involve Western coal. Thus the combined set of projects provides information on the sequence of watershed and freshwater ecological effects of Western coal use from mine through transport to power production. In addition, information is provided on the effects of coal gasification and of oil shale extraction and processing.

The second area of major emphasis concerns the effects of oil transport by pipeline through Arctic and subarctic ecosystems, emphasizing the effects of potential accidental spills. This program has been developed and is being implemented by the Arctic Environmental Research Station of the Corvallis, Oregon Environmental Research Laboratory. There are three subprojects, concerned respectively with the effects of oil spills and pipeline construction activities on arctic lakes, rivers, and small watersheds.

The small watershed study is being conducted through an interagency agreement with the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL), Ft. Wainwright, Alaska. The purpose of this project is to evaluate the rate and extent of oil movement in and over the soil active layer and to determine transport pathways, fate of pollutants, degradation products, effects on microbial populations and microbial degradation, and impact on permafrost following a simulated spill of hot crude oil on a permafrost underlain slope. The site of the study is the Caribou-Poker Creeks Research Watershed, operated by the Interagency Technical Committee for Alaska, which serves as the locale for a variety of hydrologic and environmental studies. The watershed is located in the Yukon-Tanana Uplands of central Alaska, in the zone of discontinuous permafrost. (2)

In cooperation with the Energy Research and Development Administration (ERDA) and the National Science Foundation (NSF), a study is being made of the effects of an oil spill on a large arctic lake (one of the Toolik lakes) with emphasis on the effects of this perturbation on organisms and on ecological processes in these lakes.

The third project concerns the effect of a pipeline crossing a river (the Chatanika River) in the arctic. This is primarily an in-house project, with a small grant to the University of Alaska to study the fisheries aspects. Emphasis will be on water chemistry, macrobenthos and fisheries effects, and sediment transport.

PROGRAM DISCUSSION

A. Coal and Oil Shale Mining and On-Site Conversion

This project has been underway since July 1975. Oil shale development effects are studied at the Piceance Creek site in Colorado. Strip coal mining effects are studied at the Front Creek, Colorado and Rosebud Creek-Tongue River, Montana sites. Fish and macroinvertebrate distribution studies have been started on Piceance and Front Creeks in Colorado, and on the Rosebud Creek, Tongue River, and Tongue River Reservoir in Montana. Water chemistry studies have been initiated on Piceance and Front Creeks. Microorganism studies have been started on Rosebud Creek and on cores from the Montana region. Laboratory characterization of coal, coal overburden, oil shale, and coal gasification by-products has also been started. Laboratory bioassay and bioaccumulation studies on fishes, macroinvertebrates, and microorganisms have been initiated in Montana.

B. Coal Transportation and Storage

This project is concerned with particulate and leachate transport from fine particulate coal while in storage at the Duluth-Superior port, and with the effects of these materials on aquatic biota. Work to date has been concerned with preliminary assessments in anticipation of the beginning of coal movement through the port in July 1976. The chemistry and biology departments at the University of Wisconsin, Superior and the University of Minnesota, Duluth are cooperating to characterize inorganic and organic leachates from coal and to characterize the biological condition of the bay. Some chronic bioassay exposures have begun, and other local species are being cultured for future use in bioassays. In addition, a project in the physics department of the University of Minnesota, Duluth has completed measurements of currents and water levels in the harbor. This information is being used to develop and test mathematical models of water and particulate transport in the Duluth-Superior harbor.

C. Coal-to-Electricity Power Conversion

This project at the University of Wisconsin, Madison had been ongoing for approximately four years prior to the EPA-funded expansion, with support from the Wisconsin Power and Light Company, the Madison Gas and Electric Company, and the Wisconsin Public Service Corporation. It is located at the Columbia Generating Station at Portage, Wisconsin. The Columbia Site Impact Study has completed four years of preoperational bench mark data acquisition. The study includes air, water, soil and biological parameters. A wide variety of environmental measuring equipment has been tested and placed on-line. A series of new, cheaper environmental impact measuring techniques have been developed, but not tested.

D. Oil Transport by Pipeline

Program activity to date has been concerned with calibration and baseline studies. Problems with shipment of oil prevented the planned summer application of oil to the Caribou-Poker Creeks Watershed, but oil has been received and a midwinter application is planned for this February. Another oil application will be made in June of this year. Baseline studies have been underway for several years on the Toolic lakes in connection with the U.S. International Biological Program, and will continue until July 1976. For the river crossing study a pristine river north of Fairbanks (the Chatanika River) is being characterized in anticipation of the Trans-Alaska Pipeline crossing this spring.

PROJECTION

A. Coal and Oil Shale Mining and On-Site Conversion

Research will continue toward satisfying the major project objectives. These objectives are (1) To establish data bases of information for evaluating the potential effects of coal and oil shale extraction on fresh water resources and ecosystems, (2) To conduct chemical and biological field site studies on the effects on aquatic ecosystems due to coal and oil shale extraction, including an assessment of spoils weathering, (3) To determine the acute and chronic toxicity and bioaccumulation in aquatic ecosystems of chemicals and contaminants resulting from coal and oil shale extraction, (4) To determine the potential effects on aquatic ecosystems of coal gasification products and by-products, and of oil shale conversion products and by-products, and (5) To consider the possible effects on the aquatic biota of coal-fired power-plant effluents, including rainout.

B. Coal Transportation and Storage

Research will continue toward characterizing the effects on the Duluth-Superior harbor and surrounding ecosystems of leachate from coal stored and subjected to atmospheric conditions, and to measure and model particulate dispersion from the harbor into Lake Superior. Final outputs will consist of reports on the organic and inorganic leachates from coal piles and their bioaccumulation in and effects on aquatic biota, and a generalized particulate dispersion model applicable to other planned and potential coal shipping sites on the Great Lakes.

C. Coal-to-Electricity Power Conversion

The EPA-funded expansion of this on-going project will provide support for the post-operational study in concert with the power companies and the Wisconsin Public Service Commission, which will include an increased variety of areas, integration of subprojects, and studies that will allow the extension of the findings of this project to other sites in the form of siting criteria. Subprojects include aquatic chemistry, aquatic invertebrates and fish, remote sensing, wetland ecology (plants and vertebrates), hydrogeology, air pollution modeling, plant damage, meteorology, land use, visual changes and aesthetics, stack monitoring, and project synthesis.

D. Oil Transport by Pipeline

In the Caribou-Poker Creeks Watershed the effects of winter and summer simulated hot oil spills will be monitored to determine the effects of such spills on soil microbial populations and terrestrial vegetation. In addition, the microbial degradation and photo-oxidation of the oil, its physical transport and effect on the permafrost will be monitored. This will provide information on the effects of oil from potential pipeline ruptures on undisturbed areas outside of the cleared corridor. During the second and third years of the project, an oil spill will be simulated on a disturbed, bare soil area, stripped of vegetation, resembling conditions within the pipeline corridor.

After the conclusion of the Toolic lakes baseline study in July 1976, one lake in the series will be subjected to a simulated oil spill. A predictive mathematical model will be developed to describe the effects of possible oil spills on many similar arctic lakes.

During and following the Chatanika River pipeline crossing this spring, the effects on water chemistry, fish, macrobenthos, and sediment transport will be studied intensively for one year, and less intensively for a second year. These results will be integrated with the results of a nearly completed EPA-funded project by Artec, Inc., of Columbia, Maryland on the physical transport of oil under an ice cover.

RESOURCE ALLOCATION

The total resource allocation for energy-related research in the freshwater environment since 1975 and projected through 1979 is as follows (in thousands of dollars):

	FY'75	FY'76	FY'77	FY'78	FY'79
Coal and Oil Shale	1650	1265	1265	1265	1265
Oil Spills	480	550	480	480	--

SUMMARY AND CONCLUSIONS

U.S. energy needs for the remainder of this century require greatly increased use of coal, continued reliance on oil (including that from newly discovered arctic oil fields), and possible utilization of novel sources and processing technology such as oil shale and coal gasification. In order for these activities to be conducted with minimum adverse environmental effect, considerable information is required before major development is allowed. The EPA freshwater ecological effects program is concentrating on two areas for which the information needs are most intense: coal mining, transport, and energy conversion; and oil transport by pipeline from arctic oil fields.

The coal project follows Western coal from mining in Montana and Colorado through its transport and storage in a major port facility to its combustion in a coal-fired power plant. Baseline studies, chemical characterization and ecological effects studies have been underway for approximately six months at coal mining sites in Colorado and Montana, and at the coal storage and shipping facilities at the Duluth-Superior Port. EPA funds are providing for an expansion of the coal-fired power plant to include support of the postoperational study.

The pipeline oil transport project examines three major ecosystem types likely to be impacted by an oil spill or pipeline crossing. These are (1) an undisturbed research watershed representing the headwaters of a drainage basin system, (2) a pristine river soon to be crossed by the Trans-Alaska Pipeline, and (3) a series of arctic lakes.

All of these projects are designed to provide the maximum amount of information, in the form of predictive models or other tools, for use in optimizing the location and design of future developments.

REFERENCES

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(2) Jinkinson, W.M., F.D. Lotspeich, and E.W. Mueller, 1973. Water Quality of the Caribou-Poker Creeks Research Watershed, Alaska. Working Paper No. 24, U.S. EPA, Arctic Environmental Research Station.

DISCUSSIONS FOR FRESH WATER EFFECTS SESSION

Statement from the Floor: Considerable work has been done on large river and river reservoir systems developing a tremendous amount of information for use as a common database which can be used for predictive operations. Up to this time, research had been conducted to respond to immediate problems, after the fact. An example is made for the TVA mode of operation wherein approximately half of the coal consumed is obtained from strip mining. These strip mine projects will employ a multi-disciplinary team of hydrologists, engineers, chemists and biologists, all working together to predict the consequences of mining a particular coal seam and what the necessary remedial actions will be. Predictive models should be developed and utilized to solve operational types of ecological problems.

Panel Response: The data system which has been described is being developed in coordination with EPA. This development is aimed at achieving compatability with databases under preparation by other agencies.

Statements from the Floor: TVA is pursuing two tasks relating to acute thermal effects upon insects. These tests are outgrowths of the 316A and 316B programs. We are trying to develop utility-wide or industry-wide solutions to the problems addressed. TVA is also conducting a program to determine the effects of strip mining on fresh water mollusks.

Question: Comments were made on the impact and need for treatment techniques for mining wastes which may vary considerably. This variation results from differences in mine geo-chemistry waste water characteristics, including acidity, trace metal content and suspended sediments. Treatment schemes for specific conditions are necessary instead of a single scheme for a whole area. Treatment should also consider the subject or organics in strip mine wastewaters. Is any work going on in this area?

Panel Response: It is generally agreed that organic pollutants have been neglected. The nation has become oversensitized to the metals problem as a result of our concern about methylmercury. That is not a good example to follow in the future. Metals do not pose as much of a problem as do the organics, and so should not be studied because they are so easy to measure. Ease of measurement should not be the motivation for an energy research program. Investigation of organics in mining pollution should include identification of relative toxicity of organics, and on the distribution and fate of the organics released to the ecosystem.

Additional Comment from the Floor: The Canadian program for strip mining of tar sands is now under way. One plant will process material equal to all of the coal mined in North America during an entire year. There is a ten-year program to examine the associated environmental issues which have been outlined here. Organics is seen as one of the major problems along with metals. One of the major metals is vanadium, which it is suspected, will also be found in the U.S. oil shale deposits.

Question: TVA mentioned that some coal seams are so toxic that they probably can't ever be mined. What is the nature of this toxicity?

Panel Response: The particular coal seam mentioned is one which has an overburden which results in a highly acidic spoil. A study of 400 acres of disturbed land mined from this seam shows that reclamation efforts have been unsuccessful. TVA is paying the cost of further attempts at reclamation. TVA will be hesitant in purchasing any coals mined from this seam in the future until better spoil handling techniques are developed.

Question: Was there a statement made that there are no water-related problems associated with strip mining in the West?

Panel Response: No, the Western geographic area was not specified. The intended point was that the problem associated with coal strip mining has been overemphasized in relation to, say, oil shale and coal gasification.

Comment: The question on Western strip mining of coal was mentioned in view of the imminent resumption of Federal coal leasing by the Department of the Interior, vis-a-vis the report of the National Academy of Science on the rehabilitation of strip mine areas in the West.

Panel Response: Strip mining does pose different problems in the East and the West, and for that matter, in different areas of each region.

Question: Could the panel comment on the aspect of priorities?

Panel Response: The subject of priorities is a broad one. Strip mining anywhere poses very real problems. In the West, the problem differs from that in the East due to the availability of water necessary in reclamation.

Comment from the Floor: Mention has been made of concern that there may be overemphasis on the potential problem from trace elements. Our society is very complex. Development of energy is not limited to matters of technology and environmental reality alone. Today it is necessary to consider real problems and foreseen problems. Unwelcome changes may be incorrectly blamed on the wrong culprit. Good scientific facts are going to be necessary or whole sound technologies will be hazardous. On another subject, there seems to be a race going on today to identify the most carcinogenesis material which will be evolved or emitted to the atmosphere. Caution and responsibility should be urged. There is a tendency to generate non-existent problems. Mention has been made of the great concern over mercury and metal mercury. It would be counter productive to see the same thing happen with respect to organics.

Comment from the Floor: The exaggerated concern over trace metals is the result of a bandwagon effect. The whole question of trace metals is a bad subject.

Comment from the Floor: It does seem that some of the interest in trace elements results from ease of measurement and other considerations not directly related to the hazards involved.

Comment from the Floor: In rebuttal to previous statements, trace metal analysis is not easy to do. It is not easy to do by time of adsorption or time of emission because neither has much sensitivity without prior concentration. The methodology for trace metal analysis is not easy nor has the methodology been adequately established.

Reply: The prior comment on the difficulties in measurement of trace metals was intended to be compared with the difficulties involved in the measurement of organics. It was not intended to imply that the metal measurements are easy or that they may be done by other than skilled scientists. In comparison, however, measurement of organics has the added problem that some of the compounds have not been identified as yet.

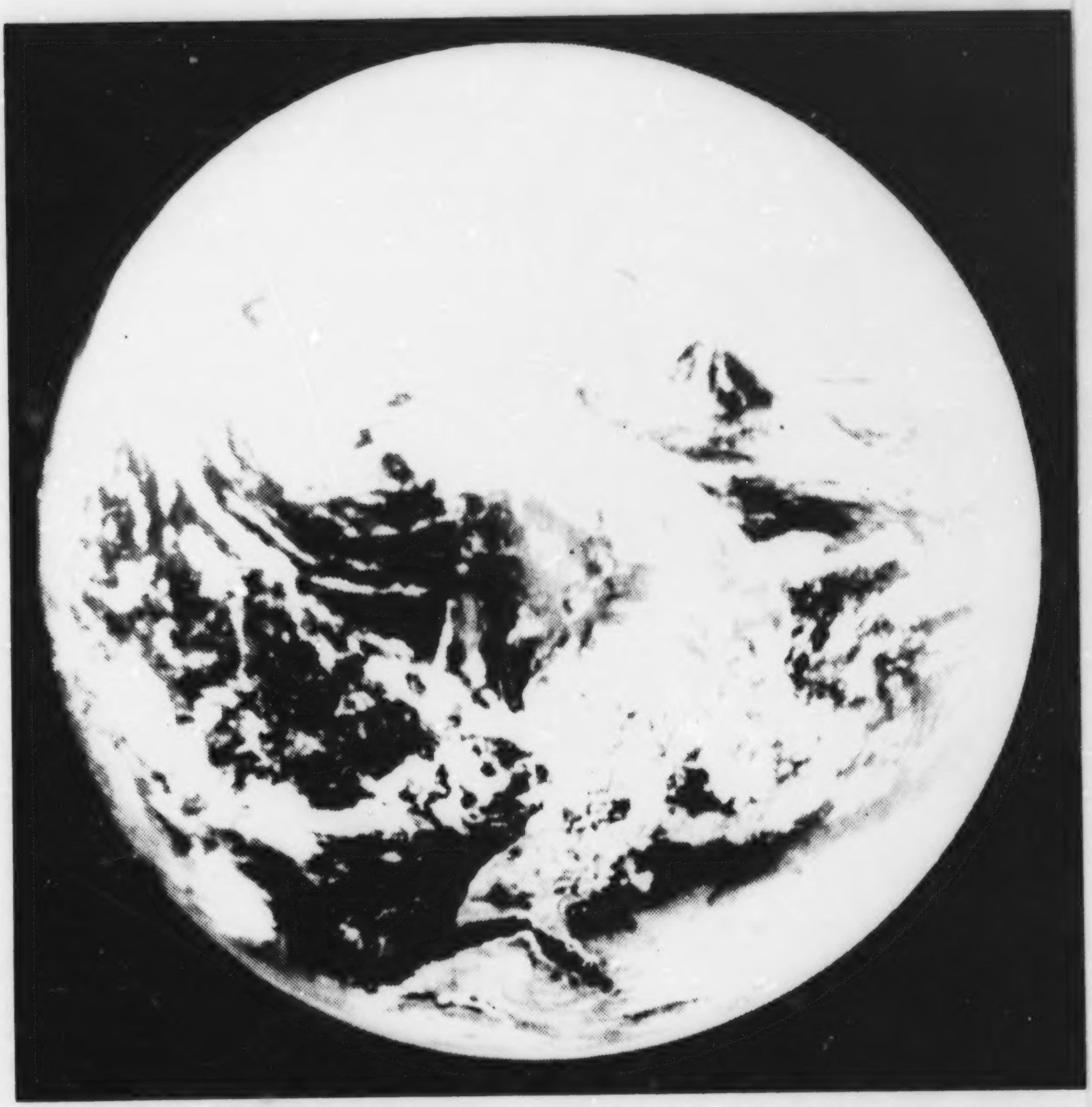
Comment from the Floor: The legislation which created ERDA is voluminous. It seems that the legislation intends to establish the vehicle where the total energy-related problem may be addressed.

Question: Are current investigations being made of ecological effects on large-scale river systems such as the upper Missouri and Colorado Basins as opposed to individual streams and rivers?

Panel Response: The Fish and Wildlife Service has initiated studies of the entire Missouri and Colorado Basins.

CHAPTER 7

TERRESTRIAL ECOLOGICAL EFFECTS



INTRODUCTION

Terrestrial ecosystems servè as sinks for pollutants deposited from the atmosphere. The most common primary pollutants emitted in the combustion of fossil fuels are compounds of sulfur, oxides of nitrogen and particulate matter. Furthermore, some of the gaseous primary pollutants undergo photochemical reactions producing even more toxic secondary pollutants. As more large coal-burning power plants are built and become operational, and as energy consumption increases in general, we may anticipate elevated concentrations of some air pollutants. Increase in the contamination of the terrestrial ecosystem can be expected to have a detrimental effect on human health and the ecosystem itself.

The chronic effects on plants from low level exposure to atmospheric pollution is not well understood compared to our understanding of acute injury. The problem of forecasting environmental consequences and of developing the technological methods to reduce or ameliorate the impact is complicated. For example, a pollutant may alter the physiology or behavior of the individuals that comprise a population. These alterations are ultimately reflected in altered survival or emigration rates. However, such effects may be subtle and difficult to relate to the specific causitive stressor. In the real world, numerous stressors are operating in complex ways. This tends to confound the field results obtained in an attempt to evaluate a single stressor. As a consequence, the terrestrial effects to be expected from various pollutants will be difficult to predict. Improvements in the predictive tools and assessment techniques remains a major research goal.

Other objectives of terrestrial related research will apply to the reclamation of damaged lands and the prevention of future damage to terrestrial ecosystems. Reclamation will be primarily associated with lands disturbed by strip mining of coal, although the technology would also probably apply to all strip mining operations including oil shale development. Prevention of future damage will result from elimination or reduction of pollutants and from reclamation practices. There is also some evidence of other protective possibility through application of chemicals which will reduce plant susceptibility.

While not typical of what should be expected from atmospheric emissions, there are also reports of beneficial results from substances ordinarily regarded as pollutants. Both sulfur and nitrogen compounds are major plant nutrients which may be supplied to some degree from the atmosphere.

Terrestrial Effects
of
Energy Research and Development

by
Norman R. Glass

INTRODUCTION

The purpose of this paper is to present a summary of the research activities which are being pursued by a number of federal agencies in the determination of the Terrestrial Effects of Energy Development. It goes almost without saying that to summarize such an extensive research program within the federal government system is a monumental task. However that may be, my intention is to summarize the research activities of the U.S. Department of Agriculture, Environmental Protection Agency, Department of Interior, Energy Research and Development Administration, and the Tennessee Valley Authority (1, 2, 3, 4, 5). This summary is only of the ecological effects portion of these agencies symposium submissions and, therefore, I will have little to say about technology oriented research programs which are reported elsewhere in this symposium.

However, before launching into detailed discussion of each of these papers, it would be worthwhile to review for you some of the background information and events which have preceeded the symposium and the results reported today. In December, 1973, a report was prepared by the chairman of the U.S. Atomic Energy Commission (now ERDA) entitled "The Nation's Energy Future" (6, 7). This report had three major recommendations attached to it:

1. A national energy and research program.
2. A five year, ten billion dollar federal ER and D program.
3. FY1975 federal budget for ER and D.

Since the exact energy extraction and conversion process dictates to a large extent the nature and extent of the ecological effects that might be expected, a word about that is in order. It is clear that fossil fuels have been the primary source of energy supplying the United States energy production system - accounting for more than 90% of the total United States energy consumption in 1973. It is also clear that even with the large increase in nuclear power generating capacity which is planned, that because of long lead times associated with getting plants on line and other factors, fossil fuels will continue to be the major energy resource at least up to and probably beyond the year 2000. Further, oil and gas are the predominating (more than 75%) fossil fuels which are satisfying U.S. energy demand. While such sources as natural gas and coal have various advantages and disadvantages, petroleum can be seen as the most versatile of our energy sources. However, both oil and gas fossil fuels may become very limited within the next decade or two, giving way to the use of coal as a primary source.

Because it is estimated that the United States has several centuries of coal availability, we are moving toward an energy economy which is based upon coal as the primary fossil fuel resource. Western coal is relatively abundant, low in cost, clean, and by about 1985 we should have a technology that is capable of economically converting western coal to synthetic gas and oil. The principal short-term constraints to the utilization of western coal reserves are the amount of environmental degradation that the American public is willing to sustein as a price for secure, abundant energy; the ability of scientists to forecast the amount and kinds of environmental effects that will result from the given level of coal use; the availability of capital; materials availability; problems relating to site selection and construction; and the availability of effective resource management systems.

It is within this framework of constraints and conditions which the Terrestrial Ecology Pass Through Program has been cast. Obviously, if coal is to become the more predominant source of fossil fuel for the United States, then the Terrestrial Ecosystem is likely to be the most heavily impacted system. However, I would not wish to understate the water resource problem particularly the matter of water availability - water quantity. Since coal extraction (primarily strip mining in recent years) has been historically concentrated in the east, in the Appalachian region, and in the mid-west, the exploitation of western coal reserves is a relatively recent phenomenon. Because of the recency of coal development on any scale in the west, programs designed to evaluate the impact of coal extraction and conversion are fairly new. Because the clean coal of the western United States is a most desirable coal to be used given the air quality constraints under which the industry operates, it seemed reasonable to devote the preponderance of research effort using "pass through" money to western coal development. By implication, because of the location of the larger reserves, most of the extraction and exploitation of western coal is in the Northern Great Plains area and the Rocky Mountain states rather than in the southwestern United States.

Our present ability to predict the effects of coal mining and coal burning is extremely limited. Indeed, we have practically no ability to predict the long term environmental effects of even the present level of coal production (see 8, 9, 10). Consequently, regardless of our intent, exploitation of this energy source may be accompanied by large-scale long-term environmental degradation. The enormity of the issue is apparent when we consider that these coal reserves might be exploited for another 400-500 years.

The problems of forecasting environmental consequences and of developing the technological methods to reduce or ameliorate impact are exceedingly complex. Both strip mining and coal combustion produce effects on living and non-living components of the environment that are extensive and diverse. While some effects may be ephemeral, others may prove to be long lasting or irreversible. Conventionally fired steam plants alone produce environmental impacts via air pollution (largely through SO_2, oxidants, particulates, and adsorbed metals), water pollution (use of cooling, makeup, and slurry water), plant construction, operation and the associated construction and employment of dams, reservoirs, aquaducts, slurry pipelines, and transmission lines. All of these have impacts both locally and at distant sites. The total direct impact of electrical energy production and delivery over a state or region may thus be very considerable in both time and space.

The major sources of cooling water, makeup water and process (slurry makeup) water are rivers such as the Yellowstone, Missouri, Tongue, and others. Therefore, vast fertile watersheds beyond the immediate area developed could be impacted. If we are to make the proper impact analysis, it is imperative that research in the Great Plains be designed to assess the long-term effects both locally and over the entire region of coal mining, conversion, delivery, and utilization.

The major air pollutants emanating from fossil fuel energy systems are the sulfur oxides, nitrogen oxides and particulate matter. These energy systems also contribute, to a lesser degree, to the carbon monoxide and oxidant burden. Primary ambient air standards based on human health effects have been established for SO_2, particulates, oxidants, hydrocarbons, and NO_2. While these standards (11, 12) were based on the best scientific information available at the time of their promulgation, significant gaps in knowledge existed. In addition to the above gaseous pollutants, many trace metals such as copper, cadmium, zinc, lead, arsenic, mercury, selenium and others, are emitted from fossil-fuel power generating plants.

Having made these introductory remarks concerning energy exploitation, I will now turn to a summary of each Agency's Terrestrial Ecology Program as submitted for this symposium by the members of the panel (1, 2, 3, 4, 5). Every effort has been made to summarize relevant material which was sent in by each Agency, any oversights are of course my responsibility.

AGENCY RESEARCH PROGRAMS

The EPA Program:

The U.S. Environmental Protection Agency in cooperation with other Federal agencies and several universities is engaged in a one million dollar per year research program at Colstrip (13, 14) designed to assess the impact of coal-fired power plants on a grassland ecosystem. This environmental research program was designed and fielded 2 years ago in anticipation of energy development in the Northern Great Plains. The major air of this four-year investigation is to develop methodologies for the prediction of impacts and thus enhance our ability to make valid siting and regulatory decisions in the future. The full realization of this objective within the time frame that has been projected will require a synthesis of effects research data and the coordination of these data with the results of socioeconomic and transport/fate research projects.

The discussion that follows is a synthesis and summary of the investigation up to the present time; for a more detailed treatment, see Lewis et al., 1975b (13, 14). This study is concerned with the stability of grassland organization in relation to ambient conditions, and with the predictability and reproducibility of changes that may occur as a function of airborne contaminants. Insight into the mechanisms of dynamic-structural responses of ecosystem components to air pollution challenge is also sought. We are also attempting to identify the subsystem functions that contribute to ecosystem regulation and the mechanisms whereby such regulation is effected. The latter is essential if we are to assess the ability of the range resource to recover or restabilize following environmental disturbance.

This investigation is a first major attempt to generate methods to predict bioenvironmental effects of air pollution before damage is sustained. Historically, most terrestrial air pollution field research has dealt almost exclusively with direct, usually acute, effects on vegetation after exposure to pollutants. We expect to observe complex changes in ecosystem dynamics as a function of relatively long-term chronic pollution challenge. We are studying a rather broad range of interacting variables, at least some of which already appear to be sensitive and reliable measures of air pollution impact.

The investigation employs 1) the use of reasonable comprehensive models of component populations of the ecosystem; 2) the use of appropriately structured field and laboratory experiments; and 3) an evaluation of selected physiological and biochemical functions that may serve as specific indicators or predictors of air pollution stress.

In addition to the "simple" direct effects of air pollutants that have been reported from experimental studies of natural systems, we know that insults to the environment from rather diverse sources (toxic substances, pesticides, radiation, disease, and adverse climate) produce a similar array of effects at the community level in spite of very different effects on individual organisms studied under experimental conditions. The response mechanisms may vary, but the manifestation is often: (1) a reversal of succession or simplification of ecosystem structure (retrogression); (2) a reduction in the ratio of photosynthesis to respiration; and (3) a reduction in species diversity at more than one trophic level, which may include the elimination of certain species (19-22) (e.g., in grassland, usually rare, but characteristic species such as those that typified the original prairie).

Effects may be temporary and reversible (i.e., the system adapts) or chronic and cumulative. In any case, if a coal-fired power plant has a measurable impact on the environment, there is every reason to believe that it will be registered as a diminution or alteration of community structure and function (22, 23, 24). Table 4 outlines the existing research plan.

TABLE 4. OUTLINE OF THE RESEARCH PLAN FOR THE MONTANA COAL-FIRED POWER PLANT PROJECT

I. Field Investigation

   A. Temporal and spatial quantitative inventory of components of the study area, with particular focus on the annual cycle phenomena of key species.

   B. Meteorological measurements to support the modeling and experimental air pollution research efforts.

   C. Development of remote sensing as a tool for detecting effects of air pollutant challenge on the ecosystem.

   D. Measurement of loss of inventory attributed to strip mining, power lines, human activity, water use, and other potentially confounding influences, e.g., pesticides, disease, population cycling.

II. Air Pollution Experiments

   A. Experimentally controlled air pollution of spatial segments of an ecosystem.

   B. Detailed measurement of biological structure and function, including energy flow, nutrient cycling and species condition, composition and diversity during and following air pollution stress.

III. Laboratory Experiments

   A. Measurement and evaluation of physiologic, biochemical and behavioral mechanisms of response to air pollution challenge.

   B. Precise measurement of parameters that support dynamic models.

   C. Experiments designed to test whether changes observed in experimental study plots can be attributed to air pollutant stress.

   D. Secondary stressor experiments (e.g., disease, temperature stress, water stress, non-specific stress).

   E. Experiments designed to test field-generated hypotheses.

IV. Modeling

   A. Use of an ecosystem level model to describe and predict effects of air pollutant challenge.

   B. Use of models to help design experiments.

   C. Use of models to help disentangle pollutant effects from natural variation and system dynamics.

   D. Meteorological and dispersion modeling to describe the mode of entry of pollutant into the ecosystem and its time and space distribution and concentrations.

In addition, field experiments are possible through the application of a zonal air pollution system designed to meet the needs and constraints of our program (25). Each grid system delivers a dilute mixture of air and SO_2 over a 1-1/4 acre grassland plot. Four plots are employed in each experiment in which median SO_2 concentrations of zero, 2, 5, and 10 pphm, respectively, are maintained throughout the entire growing season. The systems distribute the gas more or less uniformly over each plot, and the concentrations are log-normally distributed with respect to time.

The developments of an environmental assessment methodology over the next two years will require an intensive effort to integrate the immense amount of biological, chemical and physical systems information that is being generated by this program. Results of complementary investigations at Colstrip (26) will help to broaden and extend our data base and aid us in achieving our goal.

We anticipate that the effects assessment methodology developed will assist managers in siting future coal-fired power plants as well as other coal-conversion facilities.

Additional EPA Terrestrial Research

While Colstrip has been and continues to be the major EPA in-house and extramural effort in the terrestrial effects area, mention should be made of two additional points. First as presented in the freshwater effects paper by Dr. Mount, the EPA is shown as supporting about 600K in the Northern Plains region in an extramural program on watershed impacts. This work is partly terrestrial in nature in that it deals with entire watersheds. The EPA is also supporting about 100K in the Arctic for work on oil spills in the Tundra ecosystem.

The ERDA Program

There are nine tasks for which ERDA has responsibility as outlined in the interagency report deal with surface mine reclamation and related problems. With the exception of one task that is specially tailored to oil shale extraction, these tasks relate to coal extraction and utilization at mine-mouth plants. The major research efforts involve a diversified program conducted by the Land Reclamation Laboratory at Argonne National Laboratory (ANL), and the Ames Laboratory. The Ames study is a cooperative venture with the University of Montana, Montana State University, and the Pacific Northwest Laboratory. ERDA study sites are located in the Southwest, Northern Great Plains, and Central coal resource regions. The program is built around a series of mine and mine-related sites.

1. Northern Great Plains

There are four study areas in the Northern Great Plains coal region which are related to this program. They range from the lignite fields in North Dakota to the Green River Formation in Southeastern Wyoming.

Colstrip Site

The objective of the Ames project is to evaluate the significance of changes in trace element concentrations in the grassland system surrounding Colstrip, Montana, as a result of mining operations and coal utilization in the area. Initial efforts have been to determine indigenous levels of trace metals and other potential contaminants in vegetation and wildlife of the area. The goal is to provide biological transfer rates and potential effects data which can be used in the assessment of the ecological impact due to development of the region. Naturally, this study is expected to provide only a portion of the input for such an assessment.

About two-thirds of the financial support for this project comes from the trace contaminants program. The remainder of the funding is "pass through."

In addition to Colstrip, ERDA is also involved in reclamation and revegetation research efforts at the Jim Bridger Mine site, Indian Head Mine site, and Bighorn Mine site.

2. Southwestern Region

The ANL program includes three study areas in the Southwestern Coal Region; one associated with the Black Mesa mine in Arizona, and the other two in Northern New Mexico associated with the San Juan and Navajo Mines. As with other ANL studies these projects are cooperative ventures with the mine operators, and in each case regional universities are major participants in the research. These studies deal primarily with revegetation problems, topsoil salinity in mine spoil areas, alternate uses of reclaimed land, and plant growth, development, reproduction, and successional studies.

3. Central Region

Two study areas related to the interagency program are located in the Central Region, one near Morris, Illinois; the other near Staunton, Illinois.

One project will involve a demonstration effort in cooperation with the State of Illinois, coupled with an ANL research program to evaluate the effectiveness of reclamation activities that include the use of chemical soil stabilizers and soil amendments such as lime, sewage sludge, fly ash, and straw. The plan is to revegetate the site with prairie grasses, as is being done in an adjacent state park.

The second project will represent another cooperative effort by ANL to establish better methods for disposal and utilization of wastes and restoration of affected lands.

The project will include assessment of infiltration, run-off, and quality of water on the site and on adjacent, impacted areas. Both laboratory and field experiments will be performed to evaluate the effects of chemical and physical treatment on plant growth and establishment, and on microbial transformations of nitrogen and sulfur compounds.

4. Other Activities

Two other tasks from the interagency program are included in this area, one relating to oil shale extraction, the other to data management. The oil shale study, conducted by the Pacific Northwest Laboratory, involves development of a model to predict movement (either solvent or solute) through spent shale or disturbed strata under areas where shale has been extracted.

Data storage and management systems being developed in a joint effort between Oak Ridge National Laboratory and ANL will ultimately provide two-way exchange of information between Federal agencies, other public agencies, the professional community, and the coal industry. The system is planned to permit storage and retrieval of bibliographics and abstracts of reclamation research programs, data, or reports including evaluations and comments.

TRACE CONTAMINANTS FROM COAL COMBUSTION AND PROCESSING

The 1976 level of coal use in the United States was approximately 600 million tons, and forecasts indicate that this could double by the late 1980's as the nation turns to coal to alleviate dependence on foreign oil sources.

The composition of coal varies considerably, and there is no typical coal composition. Some of the trace elements of concern are cadmium, mercury, selenium, arsenic, lead, chromium, copper, and zinc. The projects included in this program are designed to determine the characteristics, transport, and fate of these trace elements in coal following combustion or conversion to synthetic fuels, and their effects on various compartments of the environment.

Some of the projects address the determination of which elements are released from a utility stack and how they are distributed in the vicinity of the plant. Another group of projects deals with the determination of trace elements in the residual fly ash and furnace ash and their mobilization following burial at disposal sites. Closely related studies address the way in which any mobilized elements are retained by different type soils.

Another aspect of this program is consideration of the manner in which the trace contaminants are cycled biogeochemically and the extent to which they are concentrated by aquatic and terrestrial organisms. In addition, some of the projects deal with effects on plant and animal species in several regions of the country.

Two of the projects will attempt to identify biological indicators which would serve as early warning systems for detection of deleterious effects.

ALASKAN OIL

As a result of the Prudhoe Bay, Alaska oil strike in 1968, there was thought to be about two billion barrels of crude oil and some 7.4 trillion cubic feet of natural gas in that field. By 1973 the proven reserves of crude oil for the U.S. and Canada, except the Arctic, were estimated to be 1.3 billion net barrels. Currently, Alaska's Arctic Slope is estimated to have something under 10 billion barrels of crude oil and about 22.5 trillion cubic feet of natural gas.

The Atomic Energy Commission was involved for many years in ecological research and studies of man's impact on the Arctic. This experience and related projects were inherited by ERDA and form the core for the future research program related to development of Alaskan resources.

ERDA has responsibility for three tasks related to these problems, as follows:

1) Oil persistence in the tundra and its impact on the below-ground ecosystem,
2) Effects of oil on tundra thaw ponds, and
3) Effects of construction on tundra lakes.

These studies were funded June 1. Therefore, few results are available and those which are available are only preliminary in scope. Additional program detail is available in ERDA's symposium submission (4).

The Department of Interior Program

The Fish and Wildlife Service energy effort is primarily concerned with minimizing the impact of energy developments on fish, wildlife, and related environmental values. This paper briefly covers the terrestrial program objectives and our current activities.

The Office of Biological Services Program has five terrestrial objectives as outlined below. These will be reviewed in detail (3), but in summary they are aimed at:

1) Defining the key terrestrial problems resulting from energy developments.
2) Obtaining the tools to deal effectively with the problem.
3) Testing and demonstrating the tools and methods under controlled conditions.
4) Learning how and where to put improved information to work on environmental problems.
5) Getting involved in the decision-making process as an active participant.

An initial program thrust of the Office of Biological Services was to establish the Western Energy and Land Use Team in Fort Collins, Colorado. Western energy reserves include extensive coal, oil shale, and geothermal reservoirs. Most of these fuels are on public land and represent national resources which are under great development pressure. The Department of the Interior places an initial priority on understanding and minimizing the energy related damage to this water poor and environmentally sensitive region. We are concerned about the surface disturbance and reclamation activities, as well as the processing and transmission of the extracted fuel. Secondary effects are also of concern. These include the protection of the environment from the development of industrail and related population growth. We will continue to place emphasis on the impact of these terrestrial activities on Western water resources which are now under severe stress.

The principal study areas under consideration include the Four Corners region, the Piceance Basin, the Powder River Basin, southeastern Montana, the Kaparowitz Plateau, and western North Dakota. They cover two of the Fish and Wildlife Service's Regions and deal with most Western major energy land disturbance problems. We will then guide our experimental studies, demonstration projects, and research activities into these areas to the degree possible.

The Fish and Wildlife Service budget provided approximately $3 million in FY 1975 to initiate the terrestrial energy projects and approximately $4 million will be available in FY 1976. These funds are supplemented by "pass through" funds from other agencies, such as the energy research and development support from the Environmental Protection Agency. Other limited support has been made available by the Bureau of Land Management and the U.S. Geological Survey. The total resource allocations since 1976 and projected through 1976 are as follows:

Upland Ecosystems Project Air/Terrestrial

FY 1975

Base	Interagency	Total
2,150K	700K	2,850K

FY 1976

Base	Interagency	Total
3,200K	700K	3,900K

The major thrust of the Fish and Wildlife Service energy program is to obtain ecological information of appropriate form and quality to effectively influence energy development decisions. This requires applying currently available techniques for ecological assessments and for significantly improving the methodologies available to measure and predict environmental impact. The Environmental Protection Agency cooperative program has allowed the Fish and Wildlife Service to undertake a serious applied research effort to improve the rate with which ecological assessments can be made. The Fish and Wildlife Service approach will involve the development of several major ecological test areas which are also of interest for Western energy development. This effort also includes extensive commitment of other Fish and Wildlife Service resources. Its success is dependent upon a high level of interagency and State cooperation on the test sites. It is anticipated that this effort will speed the decisions concerning energy development in non-sensitive areas and protect fish and wildlife values by avoidance of critical habitat and more effective reclamation procedures.

The USDA Program

EFFECTS OF AIR POLLUTANTS ON CROPS

As more large coal-burning power plants are built and become operational, we may anticipate elevated concentrations of some air pollutants. The major primary phytotoxic pollutants from these power plants are sulfur dioxide (SO_2), nitrogen oxides, acid-aerosols, ethylene, and heavy metals, like lead, cadmium, and zinc.

The chronic effects on plants of exposure to low levels of atmospheric pollutants in the environment are poorly understood as compared with our knowledge of the nature and extent of acute injury, (27, 28, 29). We do know genetic and environmental factors affect plant response to pollutants. Therefore, USDA has devoted substantial efforts to producing pollutant resistant crop varieties.

Presently, the interacting effects of toxic gas mixtures are poorly understood. A synergistic response has been demonstrated with mixtures of ozone and SO_2 (30); i.e., concentrations too low to cause visible injury when applied alone caused severe damage as a mixture. Possible damage to vegetation and soils from increased acidity of precipitation is also a problem (31).

In addition, research is being conducted with chemicals which can be applied to protect plants from injury due to oxidant air pollution. A fungicide, benomyl [methyl-1-(butylcarbamoyl)-2-benzimidazole carbamate], suppressed oxidant injury and increased yields 30 to 44% on highly sensitive Tempo beans (32).

No research information is available to accurately assess the overall impact of air pollutants on the agricultural economy. A survey by the Stanford Research Institute, available in 1971, revealed a $131 million/year loss to vegetation. If we include losses caused by minor pollutants, decreased growth and yield caused by major pollutants, effects on ornamentals, wildlife, and aesthetic values, as well as the increased value of agricultural crops since the 1971 Stanford Research Study, the $500 million/year estimated loss seems reasonable.

The effects of energy-related, air pollutants on animal production systems have not been identified. The primary concern seems to be accumulation of pollutants, like that of heavy metals in forage, in localized areas, near an industrial source or heavily traveled highways (33).

RECLAMATION OF COAL STRIP-MINED AREAS

The Department of Agriculture has been concerned for many years with revegetation of disturbed lands (34, 35). It has been an essential part of their soil and water conservation techniques.

Recent research by the Agricultural Research Service, USDA, and cooperators in Appalachia indicate (a) forage yields on reclaimed spoils are highest when rock phosphate is applied, (b) Bermudagrass has promise for revegetation if phosphorous and nitrogen deficiencies, as well as acidity, are corrected, (c) crown vetch can be established, if weeping lovergrass is used first as a covery crop, and (d) composted sewage sludge is a promising soil treatment. Currently, in West Virginia and Maryland, about 3,000 plots are involved in the revegetation studies. Our scientists are concerned also with (a) deep placement of fertilizer, (b) evaluating Rhizobium inoculants, (c) plant survival on outer slopes, (d) element uptake by various plant species, and (e) using sewage sludge as a soil amendment. ARS scientists (18) concluded that acid mine spoils in Appalachia could be altered in a relatively short time, to have good production potential. They believe that physical structure, involving available soil water and stoniness, is the most difficult to improve.

In the Northern Great Plains progress has been made in identifying factors which hinder reclamation and revegetation of strip-mine lands (36). Phosphorous is always deficient, but readily corrected by fertilization. In North Dakota spoils originating from deeper than about 15 m are frequently high in adsorbed sodium and clay content. The highly sodic spoils are impractical to reclaim because of water shortages. A series of plots were established recently which will be used to evaluate the succession of native grass species on spoils with and without top soil at various depths. Experimental results indicated considerable benefit from surface application of as little as 5 cm of natural top soil over the sodic materials. In Wyoming, new revegetation trials were established at three mine sites. For these sites a broad range of woody plant species were obtained for the revegetation trials from several sources, including the Soil Conservation Service and Federal and State Forest Service nurseries.

The Cooperative State Research Service and the State Experiment Stations of 12 coal-producing States have developed projects concerning a wide range of terrestrial environmental problems related to strip mining of coal. Most of these projects deal with revegetation of reclaimed lands. One project will investigate the effects of SO_2 pollution on native plants and crops.

The Forest Service has developed a surface environment and mining program (SEAM). Besides the several research projects already identified, they have projects on utilizing remote sensing techniques, on establishing microbial populations in sterile soils, on plant resistance to drought stress, on improved stability of mine spoils, and on evaluating strip mining effects on wildlife.

Most of the new research and development projects on revegetation of coal strip-mined lands are too new to yield results. We may anticipate that reclamation planning will be an integral part of surface coal mining operations, like those described recently in West Germany (37). A systems approach is developing which accounts for (a) land use options, (b) chemical and physical properties of the overburden, (c) mining methods that optimize separation according to quality, and the subsequent use of the overburden, (d) kinds and amounts of fertilizer and other soil amendments to use, (e) best management practices, and (f) best plant material to achieve intended land use. In addition to their use in agriculture and forestry, strip-mined areas can be used at some locations as parks, airports, sites for building schools or some types of industries, or even new towns or lakes.

The TVA Program

The efficient and responsible operation of a power system requires the development of knowledge of the ecological effects of electric generation, not only in order to avoid or lessen such environmental imapcts but also in order to avoid delays in the planning, design, and construction of power plants.

The research being conducted by TVA using pass through funds consists of one principal project with several tasks, and one lessen project, as follows:

1. Develop Baseline Information and Identify, Characterize, and Quantify the Transfer, Fate, and Effects of Coal-Fired Power Plant Emissions in Terrestrial Ecosystems in the Tennessee Valley.

A. Field and Filtered/Unfiltered Exposure Chamber Studies of Effects of Coal-Fired Power Plant Emissions on Crop and Forest Species of Economic Importance in SE United States.

The studies are being conducted at 12 sites equipped with continuous SO_2 monitors within an area near the steam plant that experiences a relatively high frequency of ground-level SO_2 exposures and at 7 sites areas remote to industrial sources of SO_2. During the 1975 growing season, comparisons of the foliar appearance, growth, and yield of soybeans, a crop species that is very sensitive to SO_2. In 1976, the studies will be expanded to include effects of SO_2 exposure on wheat, cotton, and Virginia pine. Emphasis will be placed on comparisons of plants grown on field plots with plants grown on adjacent plots equipped with air-exclusion systems. The comparisons will be made at four locations in the high exposure area and at a remote location.

B. Determine Dose-Response Kinetics for Effects of Atmospheric Emissions from Coal-Fired Power Plants on Soybeans and Other Crop and Forest Species of Economic Importance in the SE United States.

Controlled laboratory exposure studies have not reflected either the rapid changes in concentrations of principal coal-fired power plant pollutants, such as SO_2 and NO_2, that occur during ground-level exposures in the field or the environmental conditions under which such exposures normally occur; most investigators have utilized time-average concentration exposure regimes in dose-response studies.

TVA has designed, constructed, and tested a controlled SO_2 exposure system that will be employed in these studies. The system utilizes programmable fumigation kinetics to closely simulate the fluctuating SO_2 concentrations that occur in field exposures. The controlled exposure system is being modified to permit single or multiple pollutant exposures with SO_2, NO_2, and O_3.

Studies in 1975 were directed toward identifying (1) the phenological state(s) of growth at which soybean plants are most sensitive to foliar injury and to reductions in yield resulting from foliar injury and (2) the relationship between soil pH, soil fertility, and soil moisture to the SO_2 - sensitivity of soybean plants at various stages of growth. Analyses of the data are in progress.

Studies in 1976 will be directed toward (1) establishing the relationship among

SO_2 dose, foliar injury, and yield for the stage of growth that soybeans are most sensitive to yield reduction following SO_2 exposure; and (2) determining the effects of multiple pollutant exposures (SO_2 + NO_2 and SO_2 + O_3) on growth and yield of soybeans.

C. Characterize and Quantify the Transfer, Fate, and Effects of SO_x, NO_x, and Acid Precipitation on Terrestrial Ecosystems Representative of the Tennessee Valley Region.

Terrestrial and aquatic ecosystems serve as sinks for pollutants deposited in them from the atmosphere, including those emitted in the combustion of fossil fuels. Sulfur and nitrogen oxides, which are the principal atmospheric pollutants resulting from coal combustion, and their products of oxidation in the atmosphere, SO_4 and NO_3, can serve as beneficial sources of essential plant nutrients or can be toxic to living organisms. However, there is evidence that exposure to low levels of SO_2 can benefit the growth and development of plants grown on sulfur-deficient soils. The objective of the task therefore is to characterize and quantify the mechanisms of transfer of SO_x and NO_x to terrestrial ecosystems.

It is anticipated that the results of this task will be coefficients for the transfer, fate, and effects of SO_x and NO_x that can be merged with atmospheric chemistry and long-range transport studies TVA is conducting, and with data from TVA's region-wide air monitoring network, to predict and evaluate impacts on a regional basis.

D. Evaluation of the Beneficial Effects of SO_2 and Other Pollutants Emitted from Steam Plants on Crops and Forest Species, Particularly Soybeans and Pines

2. Fate and Effects of Atmospheric Emissions from Cooling Systems on Terrestrial Habitats.

Unvalidated dispersion models based on limited field data have been used to predict and evaluate the impacts of atmospheric releases from heat dissipation in the terrestrial environment. These releases include heat, moisture, salts, and potentially toxic heavy metals.

Vegetation study plots are being established at eight locations in the vicinities of each of two nuclear plants -- one equipped with mechanical draft cooling towers (Browns Ferry) and one equipped with natural draft cooling towers (Sequoyah). Growth and yield, incidence of disease, and frequency of occurrence of frost and ice injury will be determined for plantings of selected crop and timber species of economic importance. Relative humidity, temperature, precipitation, and wet and dry depositions of salts and heavy metals and their accumulation on soils and vegetation will be monitored at each plot. Data from these studies will be used (1) to validate dispersion models for these systems, (2) to determine the extent to which moisture and heat released from the two types of systems modify climate and impact vegetation, and (3) to determine whether a potential exists for salt and heavy metal toxicity to plant and livestock.

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THE ECOLOGICAL EFFECTS OF ENERGY CONVERSION ACTIVITIES ON THE TERRESTRIAL ENVIRONMENT
THE ENVIRONMENTAL PROTECTION AGENCY'S PROGRAM

Robert A. Lewis
Allen S. Lefohn
Norman R. Glass

U.S. Environmental Protection Agency
Corvallis Environmental Research Laboratory
Corvallis, Oregon 97330

INTRODUCTION

The United States is moving toward an energy economy based upon coal as the primary fossil fuel resource. Western coal is abundant, low in cost, relatively "clean" and by about 1985, we will have a technology that is capable of economically converting coal to synthetic forms of gas and oil. The proximate limitations to coal development are not primarily economic or technological. Rather, the principal short-term constraints to the utilization of Western coal reserves are the amount of environmental degradation that the American people are willing to sustain as a price for secure, abundant energy; the ability of scientists to forecast the amount and kinds of environmental effects that will result from a given level of coal use; the availability of capital; materials availability; problems relating to site selection and construction; and the availability of effective resource management systems.

Our present ability to predict the effects of coal mining and coal burning is extremely limited. Indeed, we have practically no ability to predict the long term environmental effects of even the present level of coal production (see also 1, 2, 3). Consequently, regardless of our intent, exploitation of this energy source may be accompanied by large-scale long-term environmental degradation. The enormity of the issue is apparent when we consider that these coal reserves might be exploited for another 400-500 years.

The problems of forecasting environmental consequences and of developing the technological methods to reduce or ameliorate impact are exceedingly complex. Both strip mining and coal combustion produce effects on living and non-living components of the environment that are extensive and diverse. While some effects may be ephemeral, others may prove to be long lasting or irreversible. Conventionally fired steam plants alone produce environmental impacts via air pollution (largely through SO$_2$, oxidants, particulates, and adsorbed metals), water pollution (use of cooling, makeup, and slurry water), plant construction, operation and the associated construction and employment of dams, reservoirs, aquaducts, slurry pipelines, and transmission lines. All of these have impacts both locally and at distant sites. The total direct impact of electrical energy production and delivery over a state or region may thus be very considerable in both time and space.

Strippable coal reserves lie under some of the most economically rich ranchlands and productive agricultural lands in the world. The capacity of these rangelands and grasslands to absorb or recover from strip mining, power plant siting, construction, and resultant air and water pollution is probably very limited. Yet these lands constitute a major renewable resource of the central, northcentral and midwestern United States. Considerable rangeland will be taken out of grain and livestock production; natural plant and animal populations, including species that are economically, aesthetically and recreationally valuable in the local biome will be altered or destroyed. The major sources of cooling water, makeup water and process (slurry makeup) water are rivers such as the Yellowstone, Missouri, Tongue, and others. Therefore, vast fertile watersheds beyond the immediate area developed could be impacted. If we are to make the proper socioeconomic analysis, it is imperative that research in the Great Plains be designed to assess the long term effects both locally and over the entire region of coal mining, conversion, delivery, and utilization.

The major air pollutants emanating from fossil fuel energy systems are the sulfur oxides, nitrogen oxides and particulate matter. These energy systems also contribute, to a lesser degree, to the carbon monoxide and oxidant burden. Primary ambient air standards based on human health effects have been established for SO$_2$, particulates, oxidants, hydrocarbons, and NO$_2$. While these standards (4, 5) were based on the best scientific information available at the time of their promulgation, significant gaps in knowledge existed. In addition to the above pollutants, many trace metals such as copper, cadmium, zinc, lead, arsenic, mercury, selenium and others, are emitted from fossil-fuel power generating plants. Numerous other trace contaminants in the form of hydrocarbons and various aerosols are also emitted. In general, trace metals are emitted as particles adsorbed to fly ash or other particulate matter coming from the power plant stack.

THE COLSTRIP, MONTANA PROGRAM

The U.S. Environmental Protection Agency in cooperation with other Federal agencies and several universities (Table 1) is engaged in a one million dollar per year research program (6) designed to assess the impact of coal-fired power plants on a grassland ecosystem. This environmental research program was designed and fielded in anticipation of energy development in the Northern Great Plains. The major aim of this four-year investigation is to develop methodologies for the prediction of impacts and thus enhance our ability to make valid siting and regulatory decisions. The full realization of this objective within the time frame that has been projected will require a synthesis of effects research data and the coordination of these with the results of socioeconomic and transport/fate research projects.

TABLE 1

PARTICIPANTS IN COLSTRIP PROGRAM

Federal Government	Universities
EPA	Montana State, Bozeman
USFS	University of Montana, Missoula
ERDA	Colorado State University, Fort Collins
NOAA	Oregon State University, Corvallis

The discussion that follows is a synthesis and summary of the investigation up to the present time; for a more detailed treatment, see Lewis et al., 1975b (6). This study is concerned with the stability of grassland organization in relation to ambient conditions, and with the predictability and reproducibility of changes that may occur as a function of airborne contaminants. Insight into the mechanisms of dynamic-structural responses of ecosystem components to air pollution challenge is also sought. We are also attempting to identify the subsystem functions that contribute to ecosystem regulation and the mechanisms whereby such regulation is effected. The latter is essential if we are to assess the ability of the range resources to recover or restabilize following environmental disturbance.

This investigation is the first major attempt to generate methods to predict bioenvironmental effects of air pollution before damage is sustained. Historically, most terrestrial air pollution field research has dealt almost exclusively with direct, usually acute, effects on vegetation after exposure to pollutants. We expect to observe complex changes in ecosystem dynamics as a function of relatively long-term, chronic pollution challenge. We are studying a rather broad range of interacting variables, at least some of which already appear to be sensitive and reliable measures of air pollution impact.

The investigation employs 1) the use of reasonably comprehensive models of component populations of the ecosystem; 2) the use of appropriately structured field and laboratory experiments; and 3) an evaluation of selected physiological and biochemical functions that may serve as specific indicators or predictors of air pollution stress.

Even in a comprehensive investigation, extensive studies of a large array of species or processes is not possible. Considerable research is required to identify the particular parameters that will give an adequate, sensitive measure of air pollution to a grassland ecosystem or components thereof. Broad categories of important functions under investigation include 1) changes in productivity or biomass of ecosystem compartments; 2) changes in life-cycle and population dynamic functions of "key" taxa; 3) changes in community structure or diversity; 4) changes in nutrient cycling; and 5) sublethal biochemical or physiological changes in individuals or compartments including behavioral changes.

RATIONALE

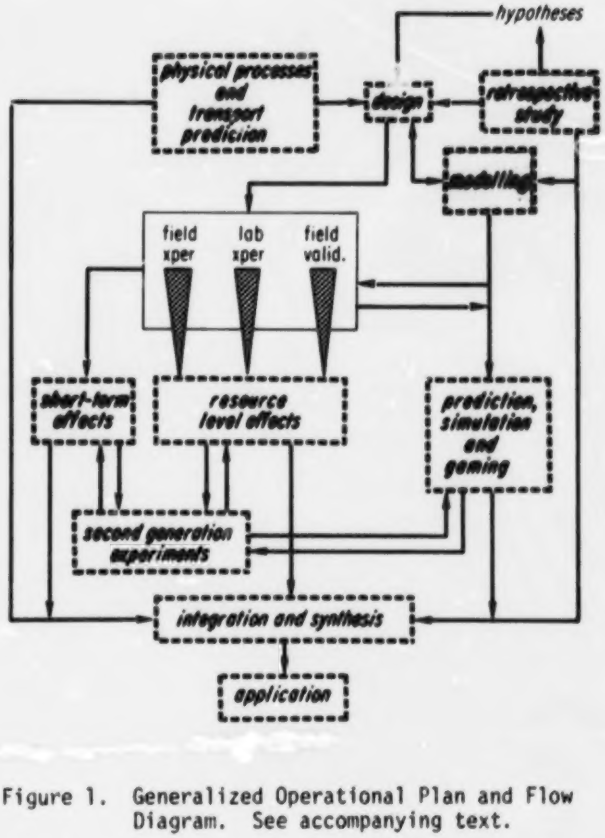
In addition to the "simple" direct effects of air pollutants that have been reported from experimental studies of natural systems, we expect to observe complex changes in ecosystem dynamics as a function of pollution challenge. We know that insults to the environment from rather diverse sources (toxic substances, pesticides, radiation, disease, and adverse climate) produce a similar array of effects at the community level in spite of very different effects on individual organisms studied under experimental conditions. The response mechanisms may vary, but results are often similar: (1) a reversal of succession or simplification of ecosystem structure (retogression)(17-14); (2) a reduction in the ratio of photosynthesis to respiration; and (3) a reduction in species diversity at more than one trophic level, which may include the elimination of certain species (11-14)(e.g., in grassland, usually rare, but characteristic species such as those that typified the original prairie) Effects may be temporary and reversible (i.e., the system adapts) or chronic and cumulative. In any case, if a coal-fired power plant has a measurable impact on the environment, there is every reason to believe that it will be registered as a diminution or alteration of community structure and function (14,15).

Both plant and animal diversity and energy transfer between and within trophic levels are measures of community structure. Furthermore, these functions may be regarded as important ecosystem resources. We hypothesize that the immediate population-level effects from environmental stress may result from differential impairment of competitive ability. At the relatively low pollution levels anticipated in the investigation, we may expect to find predisposing and subclinical effects that would be impossible to detect in the absence of appropriate population dynamic, biochemical, and physiologic information (15).

Effects need not be caused by alterations in food chains or energy flow. Certainly food chains and mass and energy flow patterns will be affected (although possibly secondarily) whenever population adjustments occur. For example, a pollutant may alter the physiology or behavior of the individuals that comprise a population. These alterations are ultimately reflected in altered survival, reproduction and/or emigration rates. Such effects may be subtle and difficult to relate to the specific stressor. In the real world, numerous stressors are operating in complex ways with various lag times; these tend to confound the results of any field evaluation of a single stressor. The end result of the response of the community to a continued environmental stress is a readjustment of the component populations (plant and animal) at a new state of dynamic equilibrium. It is not possible to predict with any confidence, either the adjustments and mechanisms most importantly involved or the final population levels that will be reached. By studying a rather broad range of interacting variables and, in particular, by an intensive study of certain populations, some may be isolated as sensitive and reliable measures of air pollution. Table 2 outlines the existing research plan.

Figure 1 is a summary of the operational plan of the project from design to application. The four major components (field and laboratory experiments, field validation, and modeling) form an integrated approach; information generated by each component is used to guide the course of the other components. The goal is to generate information on both short-term and longer-term responses and, with appropriate models, to integrate and relate these data to generate procedures for impact assessment that are truly predictive.

The field experiments referred to in Figure 1 and Table 2 are possible through the application of a zonal air pollution system designed to meet the needs and constraints of our program (17). Each grid system delivers a dilute mixture of air and SO_2 over a 1 1/4 acre grassland plot. Four plots are employed in each experiment in which median SO_2 concentrations of zero, 2, 5, and 10 pphm, respectively, are maintained throughout the entire growing season. The systems distribute the gas more or less uniformly over each plot, and the concentrations are log-normally distributed with respect to time. Chronic urban (or large area source) SO_2 concentration patterns are thus simulated. Diurnal variations are similar to those seen both from stationary point sources and in urban environments (17). The planned recruitment of a new field experimental system each year for three years will allow us to evaluate both within-year and between-year sources of variance. This temporal structure of the field experimental system will further allow us to conduct new experiments during the third year to test hypotheses generated by our field experience and modeling efforts during the first two years.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second generation experiments
integration and synthesis
application

Figure 1. Generalized Operational Plan and Flow Diagram. See accompanying text.

TABLE 2. OUTLINE OF THE RESEARCH PLAN FOR THE MONTANA COAL-FIRED POWER PLANT PROJECT

I. Field Investigation

  A. Temporal and spatial quantitative inventory of components of the study area, with particular focus on the annual cycle phenomena of key species.

  B. Meteorological measurements to support the modeling and experimental air pollution research efforts.

  C. Development of remote sensing as a tool for detecting effects of air pollutant challenge on the ecosystem.

  D. Measurement of loss of inventory attributed to strip mining, power lines, human activity, water use, and other potentially confounding influences, e.g., pesticides, disease, population cycling.

II. Air Pollution Experiments

  A. Experimentally controlled air pollution of spatial segments of an ecosystem.

  B. Detailed measurement of biological structure and function, including energy flow, nutrient cycling and species condition, composition and diversity during and following air pollution stress.

III. Laboratory Experiments

  A. Measurement and evaluation of physiologic, biochemical and behavioral mechanisms of response to air pollution challenge.

  B. Precise measurement of parameters that support dynamic models.

  C. Experiments designed to test whether changes observed in experimental study plots can be attributed to air pollutant stress.

  D. Secondary stressor experiments (e.g., disease, temperature stress, water stress, non-specific stress).

  E. Experiments designed to test field-generated hypotheses.

IV. Modeling

  A. Use of an ecosystem level model to describe and predict effects of air pollutant challenge.

  B. Use of models to help design experiments.

  C. Use of models to help disentangle pollutant effects from natural variation and system dynamics.

  D. Meteorological and dispersion modeling to describe the mode of entry of pollutant into the ecosystem and its time and space distribution and concentration.

BASIS FOR SITING THE INVESTIGATION IN SOUTHEASTERN MONTANA

The selection of an appropriate study area was deemed to be essential to structuring the entire investigation. Colstrip was selected on the basis of the initial literature review and several field trips to Montana and Wyoming. Several considerations contributed to the selection of study sites in southeastern Montana.

This region constitutes a rich rangeland resource and is climatically and ecologically representative of a relatively large portion of the North central Great Plains. Furthermore, the Colstrip area of the Fort Union Basin is a relatively pristine pine savanna area which has never been influenced by a stationary source of [toxic] gaseous or particulate emissions. Thus the vegetation and nonmigratory animals in the area, while being stressed by various environmental factors such as drought, adverse temperatures, nutrient deficiencies, etc., have never been subjected to the stress of air pollution. Existing data indicate that air quality in eastern Montana is well above the national average. Local-regional emission sources (see Regional Profile Report on Atmospheric Aspects, Northern Great Plains Resource Program, April 1974 [draft copy]) other than the coal-fired power plant at Colstrip are unlikely to contribute importantly to the air pollution burden of the Rosebud Creek Watershed during the period of investigation.

Montana laws favor rational development of resources. Consequently, the projected sites of strip-mining and power plant development are known. According to current assessments, Montana contains nearly a third of the strippable coal reserves in the northern central Great Plains and it is possible that some 120,000 acres will be stripped during the next two decades. Apart from activities associated with coal development, we expect human disturbance to be relatively low throughout the period of investigation. We feel reasonably assured that our sample sites, including buffer zones and reference sites, will remain substantially free of confounding disturbance.

Additional EPA Terrestrial Research

While Colstrip has been and continues to be the major EPA in-house and extramural effort in the terrestrial effects area, mention should be made of three additional points. First, as presented in the freshwater effects paper, the EPA is shown as supporting about 600K in the Northern Plains region in an extramural program on watershed impacts. This work is partly terrestrial in nature in that it deals with entire watersheds. The EPA is also supporting about 100K in the Arctic for work on oil spills in the Tundra ecosystem. These two projects are covered by Dr. Mount in his presentation of the EPA freshwater program. Third, the EPA is responsible for "pass through" funds provided to other federal agencies. These "pass through" program funds in the terrestrial area are shown, along with the recipient agency, in Table 3. Discussion of programs being funded with "pass through" resources is given in detail in each major agency paper.

TABLE 3

[illegible]

Project Title	Recipient Agency	Funding Level
Surface mine reclamation	[illegible]	[illegible] K
Trace contaminants from coal combustion and processing	ERDA	1,500 K
Terrestrial ecosystems near [illegible] coal-fired power plants	TVA	[illegible] K

TABLE 3 (cont'd)

Project Title	Recipient Agency	Funding Level
Terrestrial fate and effects of atmospheric emissions from cooling systems	TVA	75 K
Appraisal of research needs relative to water and ecosystem effects associated with energy development in upper Missouri river basin	DOI	100 K
Energy associated human population impacts on wildlife in Southwestern United States	DOI	200 K
Revegetation and reclamation of land areas disturbed by mining	USDA	377 K
Effects of pollutants and spoil composition on biota in semi-arid regions	USDA	270 K
Hydrologic effects of surface mining	USDA	[illegible] K
Total "pass through"		[illegible] K

CONCLUSIONS

The developments of an environmental assessment methodology over the next two years will require an intensive effort to integrate the immense amount of biological, chemical and physical systems information that is being generated by this program. Results of complementary investigations at Colstrip (18) will help to broaden and extend our data base and aid us in achieving our goal.

We anticipate that the effects assessment methodology developed will assist managers in siting future coal-fired power plants as well as other coal-conversion facilities.

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5. The Clean Air Act states that ".... air quality criteria for an air pollutant shall accurately reflect the latest scientific knowledge useful in indicating the kind and extent of all identifiable effects on public health or welfare which may be expected from the presence of such pollutants in the ambient air, in varying quantities" [section 108(a)]. The Act further states that national primary ambient air quality standards are regulations which "in the judgment of the administrator, based on such criteria, and following for an adequate margin of safety, are requisite to protect the public health" [section 109(b)]. Air quality criteria then reflect scientific knowledge, while primary

air quality standards involve a judgment as to how this knowledge must be used in a regulatory action to protect public health, and the secondary air quality standards determine the level of air quality required to protect the public welfare. Public welfare as defined in the Clean Air Act "includes, but is not limited to, effects on soils, water, crops, vegetation, manmade materials, animals, wildlife, weather, visibility, and climate ..." [section 302(h)]. These considerations also apply and become focal points for energy related environmental research. It is clear that the research experience gained in furtherance of the Clean Air Act is valuable in pursuing energy related research - in fact, the objectives of research programs are so similar that clear separation is not straight forward.

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TERRESTRIAL EFFECTS OF ENERGY DEVELOPMENT ON FISH AND WILDLIFE RESOURCES

Herbert B. Quinn, Jr.
Program Manager
Upland Ecosystems
U.S. Fish and Wildlife Service

INTRODUCTION

The national drive for energy self-sufficiency--if not properly managed--will have an adverse impact upon fish and wildlife habitat. With good design, site selection, and land use planning, however, many of these impacts will be short-term. Many of the impacts can be effectively offset or mitigated through use of technology, good reclamation practices, and the selective avoidance of critical habitat. The secondary effects of development includes the construction of transportation corridors, increased population growth in regions with limited carrying capacity, and introduction of environmental contaminants. Both the primary and secondary effects are of major concern to the Fish and Wildlife Service.

The Fish and Wildlife Service energy effort is primarily concerned with minimizing the impact of energy developments on fish, wildlife, and related environmental values. This paper briefly covers the terrestrial program objectives and our current activities.

The Biological Services Program has five terrestrial objectives as outlined below. These will be reviewed in detail, but in summary they are aimed at:

(1) Defining the key terrestrial problems resulting from energy developments.

(2) Obtaining the tools to deal effectively with the problem.

(3) Testing and demonstrating the tools and methods under controlled conditions.

(4) Learning how and where to put improved information to work on environmental problems.

(5) Getting involved in the decisionmaking process as an active participant.

1. Program Discussion

The Biological Services Program, initiated by the U.S. Fish and Wildlife Service as a major new effort in the fall of 1974, is now well under way. The Program was started in recognition of the need to mount a more concerted effort to provide ecological information in relation to many resource development decisions.

Although the Fish and Wildlife Service has had long standing environmental programs both in research and operations, Biological Services represents a major new thrust. Its goals are to strengthen the capability of the Fish and Wildlife Service in its role as primary source of information on fish and wildlife resources and their habitats, particularly in relation to environmental impact assessment; to provide an improved analytical capability and information base that will contribute to more effective recognition and protection of fish and wildlife values in land and water development decisions; and to provide better ecological input to Department of the Interior resource development programs and decisions, such as those relating to energy development.

An initial program thrust of the Office of Biological Services was to establish the Western Energy and Land Use Team in Fort Collins, Colorado. Western energy reserves include extensive coal, oil shale, and geothermal reservoirs. Most of these fuels are on public land and represent national resources which are under great development pressure. The Department of the Interior places an initial priority on understanding and minimizing the energy related damage to this water poor and environmentally sensitive region. We are concerned about the surface disturbance and reclamation activities, as well as the processing and transmission of the extracted fuel. Secondary effects are also of concern. These include the protection of the environment from the development of industrial and related population growth. We will continue to place emphasis on the impact of these terrestrial activities on Western water resources which are now under severe stress.

Although energy is clearly our first priority, we expect to expand our terrestrial ecosystems work to include other land disturbances such as non-fuels mining, agricultural practices, and the implications of urban sprawl and development on fish and wildlife habitat. Our concerns include both public and private lands.

Our second major goal is to improve approaches, tools, and methodologies for assessment of environmental impact. Concern about the problems of terrestrial development is not enough. We must provide critical information and get involved in the decisionmaking process. We find that many of the conventional approaches to terrestrial assessment do not give information soon enough or in the right form to allow it to be appropriately integrated into decisions. It is, therefore, essential that we improve the tools available to the operational manager, to get information fast and in a reliable form that can have an impact during the planning process. We will develop quantitative approaches, remote sensing, and other advanced analytical tools to demonstrate the impacts of land and related stream changes. Unless we can present hard quantitative data on an impact, we will probably not get the chance to present our case. If we present good data and provide alternative solutions which are less damaging to natural environmental values, we will have a far better chance of making a creative and constructive impact.

The principal study areas under consideration include the Four Corners region, the Piceance Basin, the Powder River Basin, southeastern Montana, the Kaparowitz Plateau, and western North Dakota. They cover two of the Fish and Wildlife Service's Regions and deal with most Western major energy land disturbance problems. We will then guide our experimental studies, demonstration projects, and research activities into these areas to the degree possible. In a sense, we are focusing our programs on where the action is.

Our fourth objective is to develop information systems and management strategies aimed at minimizing environmental damage. We anticipate a strong working relationship with States and many parts of the Department of the Interior, and close coordination of our activities with other Federal agencies. To achieve this objective we need to make our concerns known to the energy planners and resource managers early in the game. We must therefore radically improve the flow of information to them, its timeliness, and its useability. We will strengthen our working relationships with a number of Federal and State agencies whose goals are just beginning to reflect the long standing environmental concerns of the Fish and Wildlife Service.

The Service's principal energy operating elements are the Western Energy and Land Use Team in Fort Collins, Colorado, and Energy Activity staffs in the Regions. These interdisciplinary groups will initially focus on the energy developments. They will also contain disciplinary depth in a number of the required scientific areas. For example, in addition to the traditional fish and wildlife biologist, the Western Energy Team will contain capabilities in mining engineering, hydrology, economics, quantitative analysis, operations research, and remote sensing. We hope to create small centers of excellence, both within the Team and within the other parts of the Fish and Wildlife Service to improve these tools and apply them to the solution of environmental and terrestrial disturbance problems. We have to close the gap between research results and their application. It will take new research approaches and a hard-hitting operational program to make this a reality.

2. Technical Discussion

The Fish and Wildlife Service has identified a priority need for better information concerning the ecological impacts of energy developments. Unfortunately, the traditional approaches to obtaining biological baseline data are expensive, time demanding, and do not provide predictive capability.

The availability of biological information must be in phase with resource development decisions to assure its consideration. The FWS energy related program is supporting activities which provide improved methodologies for obtaining and applying baseline and impact data to energy decisions.

The timely collection, effective synthesis, and application of ecological data to areas under stress from energy development will allow better trade-offs among alternative sites. It will improve our assessment and reclamation capability and expand the base of useful ecological data--especially for sensitive and/or impacted areas.

The consideration of impacts among alternative development decisions is a complex process. The Fish and Wildlife Service is committed to improving ecological assessment procedures and entering this process. In many instances, the expensive collection of wildlife data, development of species lists and support of life histories research has not been effective in predicting ecological change or protecting critical habitat. In almost all cases, decisions for development could not wait for this research and data collection. The lack of information is especially true in the sparsely populated Western United States where wildlife values are high.

This Office of Biological Services is developing a program to obtain, analyze, and make available ecological information on terrestrial areas under stress from energy extraction and processing. The technical program will include:

(1) Improvement of ecological surveys and inventories, and monitoring procedures.

(2) Improvement of ecosystems classification techniques.

(3) Assessment of various developments on ecosystems.

(4) Improvement of predictive capability.

(5) Improvement of means of mitigating adverse impacts.

The development of improved methodologies must be in phase with active energy development decisions and on-going baseline studies. The use of ecological test areas provides a means of focusing these activities in priority energy areas. The test areas also allow the Fish and Wildlife Service to effectively utilize the research and data available from other agencies working in these energy areas.

An important requirement of all research and survey activity is to assure compatibility of the information to concepts of ecosystems mapping techniques and automatic data processing. The studies on test areas will contribute to the ecological data base which will be used to characterize the region's ecosystems and functional components. These selected test areas will be an initial part of a comprehensive program to characterize major ecosystems in the United States.

The Upland Ecosystems Project will immediately characterize selected areas under stress from energy development using existing information from Federal and State files and results from on-going research. In addition, a major effort will be made--in cooperation with the Environmental Protection Agency--to develop rapid assessment techniques for habitat characterization. This effort will use improved statistical and data acquisition procedures to characterize habitat within acceptable confidence limits.

3. Projection

In FY 1976, we will initiate studies and surveys on up to six major Western energy sites to serve as ecological test areas. Detailed research plans that address operational and methodological needs will be designed for each site by the Western Energy and Land Use Team. The following map shows these test areas. A great deal of the Team's effort, including the efforts of contractors, will be spent on these sites to provide baseline information and develop methods to assess the impacts of energy developments. Application of remote sensing techniques and development of related interpretive methods for habitat characterization will be a major purpose for these test sites. Other Fish and Wildlife Service energy related activities will involve analysis of Eastern and mid-continental wildlife problems. The Service anticipates projects in regional analysis of extraction related wildlife problems, development of species, bibliographic and geographic wildlife information systems geared to address energy problems and further development of biotelemetry as a tool for habitat assessment.

INTERAGENCY PARTICIPATION

A substantial portion of the terrestrial ecosystems activity is being funded by Interagency Supplemental Energy Funds. The Fish and Wildlife Service is also working cooperatively with the Department of Agriculture and other Bureaus of the Department of the Interior in this effort. The ecological test area concept discussed in this paper represents an outstanding opportunity for interagency cooperation. Many of these test sites involve research conducted by other agencies and provide a need for effective coordination of work as well as pooling of resources and data. To the degree possible, the Fish and Wildlife Service will consider serving as a coordination point for ecological baseline data for other interested agencies and industrial participants. The extensive Federal/State/private industry activities on the Western energy areas makes a high degree of coordination desirable if not essential. In addition, many State and Federal agencies have unique capabilities and information for research or methodological development which are needed by the Fish and Wildlife Service in characterizing these sites.

The Fish and Wildlife Service resources are not sufficient to conduct the full range of studies and assessments needed for ecological characterization and prediction on all test areas. Therefore, the Service expects to actively work with other agencies to assure that limited resources are best applied and unnecessary overlap is avoided.

RESOURCE ALLOCATION

The Fish and Wildlife Service budget provides approximately $3 million in FY 1975 to initiate the terrestrial projects and approximately $4 million will be available in FY 1976. These funds are supplemented by transfer funds from other agencies, such as the energy research and development support from the Environmental Protection Agency. Other limited support has been made available by the Bureau of Land Management and the U.S. Geological Survey. The total resource allocations since 1975 and projected through 1976 are as follows:

Upland Ecosystems Project
Air/Terrestrial
($ x 10^6)

FY 1975			FY 1976		
Base	Interagency	Total	Base	Interagency	Total
2,150	700	2,850	3,200	700	3,900

CONCLUSIONS

The major thrust of the Fish and Wildlife Service energy program is to obtain ecological information of appropriate form and quality to effectively influence energy development decisions. This requires applying currently available techniques for ecological assessments and for significantly improving the methodologies available to measure and predict environmental impact. The Environmental Protection Agency cooperative program has allowed the Fish and Wildlife Service to undertake a serious applied research effort to improve the rate with which ecological assessments can be made. The Fish and Wildlife Service approach will involve the development of several major ecological test areas which are also of high interest for Western energy development. This effort also includes extensive commitment of Fish and Wildlife Service resources. Its success is dependent upon a high level of interagency and State cooperation on the test sites. It is anticipated that this effort will speed the decisions concerning energy development in non-sensitive areas and protect fish and wildlife values by avoidance of critical habitat and more effective reclamation procedures.

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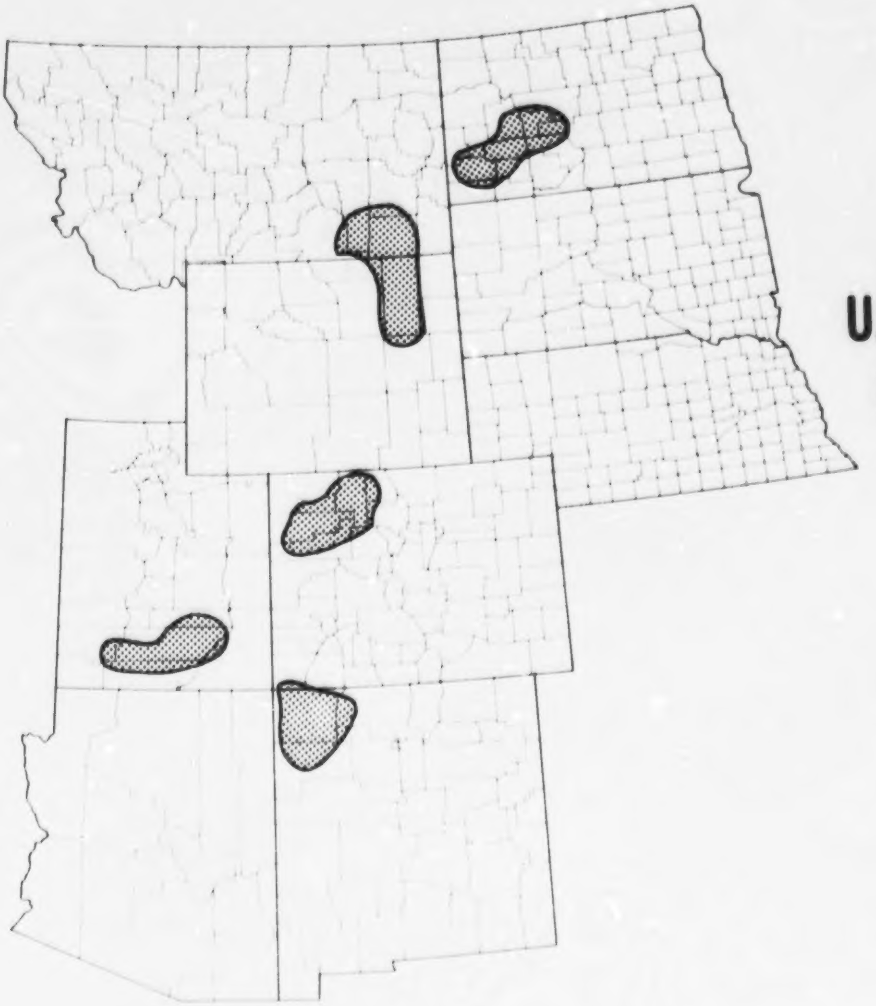

U.S. Fish and Wildlife Service Ecological Test Areas

Air/Terrestrial Ecological Effects

H. R. Hickey and P. A. Krenkel
Tennessee Valley Authority
Chattanooga, Tennessee

INTRODUCTION

The efficient and responsible operation of a power system requires the development of knowledge of the ecological effects of electric generation, not only in order to avoid or lessen such environmental impacts but also in order to avoid delays in the planning, design, and construction of power plants.

From its very beginning, TVA has engaged in large-scale resource development programs and has developed an internal capability for evaluating and managing the effect of those programs on the environment. The applied research described here consists of one principal project with several tasks, and one lesser project, as follows:

1. Develop Baseline Information and Identify, Characterize, and Quantify the Transfer, Fate, and Effects of Coal-Fired Power Plant Emissions in Terrestrial Ecosystems
    - A. Field and Filtered/Unfiltered Exposure Chamber Studies of Effects of Coal-Fired Power Plant Emissions on Crop and Forest Species of Economic Importance in SE United States
    - B. Determine Dose-Response Kinetics for Effects of Atmospheric Emissions from Coal-Fired Power Plants on Soybeans and Other Crop and Forest Species of Economic Importance in the SE United States
    - C. Characterize and Quantify the Transfer, Fate, and Effects of SO_x, NO_x, and Acid Precipitation on Terrestrial Ecosystems Representative of the Tennessee Valley Region
    - D. Evaluation of the Beneficial Effects of SO_2 and Other Pollutants Emitted from Steam Plants on Crops and Forest Species, Particularly Soybeans and Pines
2. Fate and Effects of Atmospheric Emissions from Cooling Systems on Terrestrial Habitats

These projects and tasks are described below.

For possible use in the exchange of information or coordination, the names of principal investigators, research investigators, and responsible administrators are included after the title of each task.

DISCUSSION

1. Develop Baseline Information and Identify, Characterize, and Quantify the Transfer, Fate, and Effects of Coal-Fired Power Plant Emissions in Terrestrial Ecosystems

A. Field and Filtered/Unfiltered Exposure Chamber Studies of Effects of Coal-Fired Power Plant Emissions on Crop and Forest Species of Economic Importance in SE United States--

H. C. Jones, N. T. Lee, J. C. Noggle, N. L. Lacasse, W. R. Nicholas

There is insufficient information for predicting and evaluating the impact of atmospheric pollutants emitted from coal-fired power plants on the appearance, growth, and yield of crop and timber species grown under field conditions. For example, it can be concluded from EPA's revised air quality criteria for SO_2 effects on vegetation that SO_2 dosages (time-concentrations) greater than 0.5 ppm for 1 hour can cause visible injury to the foliage of sensitive species. However, the relationships between visible foliar injury and permanent economic, ecologic, or esthetic damage are less clearly understood, particularly under conditions that normally occur in the field. Similarly, there is considerable concern over the effects of long-term exposure of plants to low levels of SO_2, alone or in combination with low levels of other pollutants, but little hard evidence exists to confirm that such effects occur in the ambient environment. The objective of this task is to identify and quantify these impacts for selected sensitive plant species of economic importance in terms that can be used in evaluating the impacts of emissions from existing or proposed power plants. This task is an expansion and refinement of research TVA has been conducting in the vicinity of its 1900-MW Widows Creek Steam Plant for the last four years.

The studies are being conducted at 12 sites equipped with continuous SO_2 monitors within an area near the steam plant that experiences a relatively high frequency of ground-level SO_2 exposures and at 7 sites areas remote to industrial sources of SO_2. During the 1975 growing season, comparisons of the foliar appearance, growth, and yield of soybeans, a crop species that is very sensitive to SO_2, were made for the following sets of conditions:

1. Plants grown in containers at field plots in the exposed area with those grown in the remote (control) locations.
2. Plants grown in ambient/charcoal-cleaned air in partitioned greenhouse exposure chambers at a single location in the exposed area.

3. Plants grown in a plot equipped with a prototype air-exclusion system, which utilizes "purified" air to exclude or partially exclude air containing SO_2 when ambient SO_2 concentrations equal or exceed 0.1 ppm, with plants grown on an adjacent plot from which SO_2 was not excluded or limited.

Data from the 1975 studies are being analyzed.

Studies conducted by TVA over the past five years have shown that soybeans grown in ambient air in field exposure chambers consistently produced lower yields than those grown in charcoal-cleaned air. However, similar effects on yield have not been detected in field plots. These results, which are similar to those reported by other researchers using open-top field exposure chambers, indicate that comparisons of effects of pollutants on plants grown in field exposure chambers might not be valid because environmental conditions within the chambers could make the plants more sensitive to ambient levels of pollutants than they would be in the natural environment. The prototype ambient air-exclusion system places an air barrier between the plant study plot and the polluted air only during periods of ground-level exposures thereby eliminating the unnatural environmental conditions associated with chambers. The system permits comparisons between plants exposed to SO_2 with those from which damaging SO_2 concentrations have been excluded at the same sites under essentially identical edaphic, climatic, and cultural conditions.

In 1976, the studies will be expanded to include effects of SO_2 exposure on wheat, cotton, and Virginia pine. Emphasis will be placed on comparisons of plants grown on field plots with plants grown on adjacent plots equipped with air-exclusion systems. The comparisons will be made at four locations in the high exposure area and at a remote location.

B. Determine Dose-Response Kinetics for Effects of Atmospheric Emissions from Coal-Fired Power Plants on Soybeans and Other Crop and Forest Species of Economic Importance in the SE United States--N. T. Lee, H. C. Jones, N. L. Lacasse, W. R. Nicholas

Controlled laboratory exposure studies have not reflected either the rapid changes in concentrations of principal coal-fired power plant pollutants, such as SO_2 and NO_2, that occur during ground-level exposures in the field or the environmental conditions under which such exposures normally occur; most investigators have utilized time-average concentration exposure regimes in dose-response studies. Furthermore, dose-response data are meager for species of economic or ecologic importance to the Southeast. The objectives of these studies are to determine the individual and combined effects on vegetation of SO_2, NO_2, and O_3 exposures at concentrations, dosage rates, and environmental conditions typically occurring during surface exposures in the vicinities of large coal-fired power plants and to determine appropriate time-concentration relationships for evaluating exposure hazards from SO_2 and NO_2.

TVA has designed, constructed, and tested a controlled SO_2 exposure system that will be employed in these studies. The system utilizes programmable fumigation kinetics to closely simulate the fluctuating SO_2 concentrations that occur in field exposures. The controlled exposure system is being modified to permit single or multiple pollutant exposures with SO_2, NO_2, and O_3.

Studies in 1975 were directed toward identifying (1) the phenological stage(s) of growth at which soybean plants are most sensitive to foliar injury and to reductions in yield resulting from foliar injury and (2) the relationship between soil pH, soil fertility, and soil moisture to the SO_2-sensitivity of soybean plants at various stages of growth. Analyses of the data are in progress.

Studies in 1976 will be directed toward (1) establishing the relationship among SO_2 dose, foliar injury, and yield for the stage of growth that soybeans are most sensitive to yield reduction following SO_2 exposure; and (2) determining the effects of multiple pollutant exposures (SO_2 + NO_2 and SO_2 + O_3) on growth and yield of soybeans.

C. Characterize and Quantify the Transfer, Fate, and Effects of SO_x, NO_x, and Acid Precipitation on Terrestrial Ecosystems Representative of the Tennessee Valley Region--H. C. Jones, J. C. Noggle, J. M. Kelly, W. R. Nicholas

Terrestrial and aquatic ecosystems serve as sinks for pollutants deposited in them from the atmosphere, including those emitted in the combustion of fossil fuels. Sulfur and nitrogen oxides, which are the principal atmospheric pollutants resulting from coal combustion, and their products of oxidation in the atmosphere, SO_4 and NO_3, can serve as beneficial sources of essential plant nutrients or can be toxic to living organisms. SO_2, when it exceeds an average concentration of 0.5 ppm for 1 hour with an associated peak concentration higher concentrations may cause permanent economic, esthetic, or ecologic damage. However, there is evidence that exposure to low levels of SO_2 can benefit the growth and development of plants grown on sulfur-deficient soils. Sulfates and nitrates are important plant nutrients. There are indications that modern fertilizer practices are causing sulfur deficiencies over sizable areas of the United States because the newer, high-analysis fertilizers contain little or no sulfur. However, unneutralized sulfates or nitrates in sufficient quantities may react with moisture in the atmosphere to form acidic rain that might adversely affect vegetation and soil microbes by direct contact or might indirectly result in conditions that are unfavorable for plant growth and survival by increasing the acidity of soils. The objective of the task, therefore, is to characterize and quantify the mechanisms of transfer of SO_x and NO_x to terrestrial ecosystems and the extent to which these pollutants cause adverse or beneficial impacts.

Three essentially undisturbed oak-hickory watersheds at three distances from a large 1900-MW, coal-fired steam plant have been selected for study. The sandy loam soils of the watersheds are derived from sandstone. They are naturally acidic and possess low buffering capacity and should exhibit maximum sensitivity to acidic precipitation. The streams draining the watersheds, while barely neutral, also have a low buffering capacity. One of the watersheds is located within 10 miles of the SO_2 source, is frequently exposed to SO_2, and will be used primarily to characterize the transfer of gaseous SO_2 and NO_2 to the oak-hickory ecosystem. The second watershed, which is exposed to low levels of SO_2, is located about 25 miles from the source at a distance where oxidation products--SO_4 and NO_3--should begin to occur in significant amounts. The third watershed is located in an area that is remote (50 miles) from industrial sources of SO_2, is comparatively SO_2-free, and would be expected to reflect only the impacts of sulfate and nitrate depositions, if they exist.

At each location, wet and dry deposition of gaseous and particulate SO_x and NO_x and other airborne pollutants are being characterized and quantified in open areas and above, within, and below the forest canopy. Absorption and adsorption of SO_x and NO_x by vegetation and soils on the plots will be characterized, as well as impacts on vegetation and soils. The studies are being designed so that impacts on water quality can also be ascertained if funds are available. Because the watersheds have been subjected to SO_x and NO_x pollution for some time, and to enhance the probability of detecting impacts on soils if they are occurring, portions of the watersheds will be limed and fertilized. Necessary supportive meteorological and climatological data will also be collected.

Controlled laboratory studies using simulated acidic precipitation of varying ionic composition and acidity are also planned to obtain supporting data on the impacts of SO_x and NO_x. These studies will use acidic precipitation with ionic compositions and acidities simulating that actually measured in TVA's region-wide precipitation monitoring network.

It is anticipated that the results of this task will be coefficients for the transfer, fate, and effects of SO_x and NO_x that can be merged with atmospheric chemistry and long-range transport studies TVA is conducting, and with data from TVA's region-wide air monitoring network, to predict and evaluate impacts on a regional basis.

D. Evaluation of the Beneficial Effects of SO_2 and Other Pollutants Emitted from Steam Plants on Crops and Forest Species, Particularly Soybeans and Pines--J. C. Noggle, H. C. Jones, W. R. Nicholas

Sulfur is one of the major nutrients essential for plant growth. The amounts of sulfur absorbed by medium to high yields of crops range from 8 to 35 pounds per acre. The amounts of sulfur and phosphorus needed by crops are similar but higher amounts of nitrogen and potassium are needed. In humid regions most of the sulfur in soils is present as proteinaceous compounds in soil organic matter or is held as sulfate (SO_4) by the clay fraction. The sulfur in organic matter is gradually released as SO_4-S as a result of decomposition by microorganisms. In general, retention of soluble SO_4-S by sand or silt-textured soil is one year or less, especially in areas of high winter rainfall. Sulfur is lost from the soil by crop removal and leaching.

For many years, fertilizers have been added to supplement the primary nutrients--nitrogen, phosphorus, and potassium--in soil. Prior to about 1950, the relatively low-analysis commercial fertilizers were based primarily on ordinary superphosphate (18 to 20% P_2O_5 and 14% S) and ammonium sulfate (21% N and 24% S) was a leading source of nitrogen. As a result of using these fertilizers, adequate sulfur was usually present in the fertilizers for crops, and sulfur-deficiencies were not detected in many crop areas. The recent trend has been to high-analysis fertilizers that contain little or no sulfur, and higher crop yields have increased sulfur demand. During this latter period numerous cropping areas, remote from industrial sites, have been identified as having soils that are sulfur-deficient. As a result, some states require that sulfur be added to fertilizers. The lack of sulfur-deficient soils in industrial areas indicates that atmospheric sulfur is, in effect, replacing commercial fertilizers as a source of this essential plant nutrient.

The quantity of sulfur contributed by the atmosphere to meet the S requirements of crops and forests has not been adequately evaluated. Although measurements have been made of the amount of sulfur in rainfall and dry particulate deposition, field observations of SO_2 sorption by soil and plant foliage are limited. Laboratory experiments have shown that significant amounts of SO_2 were sorbed by soil and other investigators have reported direct absorption of SO_2 by plant foliage. To determine the total sulfur contribution by the atmosphere, the amount of sulfur in each method of entry into the terrestrial ecosystem will be measured in the field.

About 1.1 million tons of sulfur are applied in fertilizer annually in the United States. At the 1975 cost of $55 per ton, the annual cost is about $60 million. The potential annual consumption of fertilizer sulfur in the United States is estimated at 2.5 million tons, which represents a value of \$137 million. After the amount and distribution of sulfur deposition from the atmosphere are determined, the impact on plant needs and fertilizer requirements can be evaluated.

Nitrogen entering the terrestrial ecosystem from steam plant emissions will be beneficial as an essential plant nutrient. Measurements of nitrogen entry will be made with sulfur determinations.

The possible beneficial effect of SO_2 on vegetation by increasing the density of wood in SO_2-resistant pines will also be studied.

2. Fate and Effects of Atmospheric Emissions from Cooling Systems on Terrestrial Habitats--H. C. Jones, J. M. Kelly, W. R. Nicholas

Unvalidated dispersion models based on limited field data have been used to predict and evaluate the impacts of atmospheric releases from heat dissipation in the terrestrial environment. These releases include heat, mositure, salts, and potentially toxic heavy metals. The dispersion models indicate insignificant environmental impacts of emissions from either mechanical draft or natural draft cooling tower systems using freshwater, but there are few hard field data confirming the predictive capabilities of these models. The objective of this project, therefore, is to identify and characterize the effects of atmospheric releases from power plant cooling systems on terrestrial habitats.

Vegetation study plots are being established at eight locations in the vicinities of each of two nuclear plants--one equipped with mechanical draft cooling towers (Browns Ferry) and one equipped with natural draft cooling towers (Sequoyah). Growth and yield, incidence of disease, and frequency of occurrence of frost and ice injury will be determined for plantings of selected crop and timber species of economic importance. Relative humidity, temperature, precipitation, and wet and dry depositions of salts and heavy metals and their accumulation on soils and vegetation will be monitored at each plot. Data from these studies will be used (1) to validate dispersion models for these systems, (2) to determine the extent to which mositure and heat released from the two types of systems modify climate and impact vegetation, and (3) to determine whether a potential exists for salt and heavy metal toxicity to plant and livestock.

TERRESTRIAL EFFECTS OF POLLUTANTS FROM ENERGY USE AND PROGRESS IN RECLAMATION OF COAL STRIP MINE AREAS

H. E. Heggestad
Agricultural Research Service
U.S. Department of Agriculture

TERRESTRIAL EFFECTS OF AIR POLLUTANTS

The combustion of fossil fuels to release useful energy produces gaseous and particulate pollutants. Furthermore, some of the gaseous primary pollutants undergo photochemical reactions, producing even more toxic secondary pollutants, like ozone. Air pollutants related to energy use can have subtle and widespread environmental impacts.

As more large coal-burning power plants are built and become operational, we may anticipate elevated concentrations of some air pollutants. The major primary phytotoxic pollutants from these power plants are sulfur dioxide (SO_2), nitrogen oxides, acid-aerosols, ethylene, and heavy metals, like lead, cadmium, and zinc.

Some adverse consequences from developing our energy-producing resources, like failing to restore land after strip mining coal, also give cause for concern. These are usually gross, localized effects.

The chronic effects on plants of exposure to low levels of atmospheric pollutants in the environment are poorly understood as compared with our knowledge of the nature and extent of acute injury, (1, 2, 3). We do know genetic and environmental factors affect plant response to pollutants. Cultivars have been identified with a range of tolerances to air pollutants. Some are promising to maintain high productivity in polluted areas where less resistant cultivars yield poorly. With change to resistant cultivars in annual crops production losses may be reduced in a single year, but with perrenial crops it may require many years to get a resistant cultivar into production. Using pollution-resistant cultivars may be a suitable alternative in some agricultural areas to very restrictive air-quality standards. Complex natural ecosystems may be protected most effectively by maintaining suitable air quality.

Presently, the interacting effects of toxic gas mixtures are poorly understood. A synergistic response has been demonstrated with mixtures of ozone and SO_2 (4); i.e., concentrations too low to cause visible injury when applied alone caused severe damage as a mixture. Other studies (5) have shown that lower concentrations of SO_2 and NO_2, as a mixture, were needed to depress the photosynthesis rate of alfalfa. A 2-hr exposure to 0.25 ppm SO_2 inhibited photosynthesis 2 to 3% while a similar NO_2 exposure caused no measurable depressions. However, exposure to 0.25 ppm mixture of both gases simultaneously produced 9 to 15% inhibition. Within 30 minutes to 2 hours after the toxicants were removed, the photosynthetic rates usually recovered to control levels. A few hours of reduced photosynthetic rate, however, may not alter productivity. Reduced growth and chronic injury are expected only after long-term or repeated exposures to phytotoxic air pollutants and their mixtures at subacute concentrations. Recent studies in Germany identified a potential new air pollution problem. In the presence of increased cadmium concentrations, SO_2 was more damaging to plants than at low cadmium concentrations (6).

Ethylene, a hydrocarbon resulting from fuel combustion, is an unusual air pollutant since it is also a plant hormone. Vegetation is also a source of low concentrations of ethylene. Ethylene concentrations are mugh higher in urban centers with a high density of motor vehicles than in suburban or rural areas, ranging from 0.7 ppm in the inner city of Washington, D.C., to 0.039 ppm at nearby Beltsville, Maryland (7). In rural areas they are usually lower than 0.005 ppm. Several plant species continuously exposed to air containing 0.025 ppm ethylene showed poor growth, premature senescence, and decreased flowering and fruiting. Thus, ethylene may be a significant pollutant in cities, reducing the growth and value of some tree and ornamental species. Its chronic effects are not easy to distinguish from those of other gas pollutants and environmental stresses.

Possible damage to vegetation and soils from increased acidity of precipitation is also a problem. In May, 1975, the First International Symposium on Acidic Precipitation and the Forest Ecosystem reported that it caused direct injury to foliage; decreased spruce-seed germination; increased leaching of nutrients from foliage and humus; increased erosion of waxes on oak and bean leaves; decreased nitrogen uptake by endomycorrhizae of sweet gum seedlings; and inhibited the nodulation and nitrogen fixation by Rhizobium in bean and soybean seedlings (8). On the other hand, it inhibited the reproduction of root knot nematodes and the development of bean rust. Like other pollutants, the possible economic consequences of such biotic effects of acidic precipitation are not known.

Assessing Air Pollution Effects

Air pollution effects on agricultural productivity under field conditions have been assessed by several investigators. Only limited progress has been made by using chambers in the field, since they alter plant response to the pollutants. Chamber effects were minimized by the development of "open" top chambers, first described in 1973 (9, 10). Their designs vary, but most chambers are 3 m in diameter and 2.4 m high, with blowers supplying either carbon-filtered or unfiltered air near the chamber bottom. Except in stagnated air at low wind speeds, varying amounts of ambient air enter the chamber top. Consequently, their efficiency in removing pollutants may average only 70%. However, their efficiency is highest when oxidants are highest since pollutants accumulate during periods with low wind speeds.

Since 1972, open-top chambers have been studied at Beltsville, Maryland, using snap beans (11). After 3 years with two snap bean crops each year, one of three cultivars averaged a 14% decrease in bean yield in unfiltered air chambers. For the two, more resistant cultivars, yield differences were not significant. Except for one of six crops production in plots without chambers equalled that in chamber plots with unfiltered air.

Other approaches have been used to assess the impact of air pollutants on field-grown plants. Chemicals have been applied to protect plants from injury due to oxidant air pollution. A fungicide, benomyl [methyl-1-(butylcarbamoyl)-2-benzimidazole carbamate], suppressed oxidant injury and increased yields 30 to 44% on highly sensitive Tempo beans (12). Oxidant leaf injury and yield of Pinto bean were decreased. However, Tenderwhite, the most tolerant cultivar, showed no difference in oxidant leaf injury or yield for sprayed and unsprayed plots, suggesting adequate resistance at least for the test conditions at Waltham, Massachusetts.

Unless the chemical protectant has systemic action, it must be applied frequently to maintain leaf surface coverage. Chemical protectants have one advantage over chambers in assessing air pollution impact, since they do not alter the plant environment. Possibly, chamber design can be improved to minimize chamber effects and to increase filtration efficiency. There is a need to reduce entrance of unfiltered air through the chamber top.

Assessing the impact of SO_2 on vegetation under field conditions is more difficult, since convenient, long-term filters are not available to effectively remove SO_2 nor are there chemicals to protect from SO_2 injury. Also, different approaches are needed to assess pollutants from single sources than from multiple or diffuse sources. However, field studies have been conducted to assess the impact of SO_2 pollution.

In one study (13), many acres of soybeans near a large, coal-fired, electric-generating station were exposed to SO_2 levels which caused severe leaf injury at a relatively early stage in plant development; i.e., before blooming, when plants were about 0.5 m tall. Eighteen variables, including SO_2 leaf injury, were examined to assess possible yield losses attributable to SO_2. The SO_2-induced leaf injury was not a significant factor in accounting for yield variation from the 110 fields studied. Poor yields were associated with factors like low soil fertility, soybean cyst nematode infestation, continuously soybean cropping, and late planting, rather than to SO_2 injury. Apparently, the affected plants attained normal or near normal growth after SO_2 injury.

No research information is available to accurately assess the overall impact of air pollutants on the agricultural economy. A survey by the Stanford Research Institute, available in 1971, revealed a $131 million/year loss to vegetation. Of this amount, $121 million (more than 90%) was attributed to oxidants, $6 million to SO_2, and $4 million to fluorides. In the past, gross estimates by others have exceeded $500 million/year. If we include losses caused by minor pollutants, decreased growth and yield caused by major pollutants, effects on ornamentals, wildlife, and esthetic values, as well as the increased value of agricultural crops since the 1971 Stanford Research Study, the $500 million/year estimated loss seems reasonable.

Recently, an assessment of the impact of gaseous air pollution on the quantity and quality of crops was recommended as a high-priority research item (14). Approaches include using chambers and/or chemicals to exclude or inactivate a pollutant, differentially tolerant cultivars, and various pollutant doses in field chambers. In studies involving pollutants from point sources, the investigator may utilize natural pollutant gradients.

The effects of energy-related, air pollutants on animal production systems have not been identified. The primary concern seems to be accumulation of pollutants, like that of heavy metals in forage, in localized areas, like near an industrial source or heavily traveled highways (15).

RECLAMATION OF COAL STRIP-MINED AREAS

The total U.S. land area disturbed by surface mining currently exceeds 1,600,000 ha, about half of which has resulted from coal mining operations (16). The Geological Survey estimates that about 4,287 mi^2 (1,100,000 ha) will have been stripped by 1980. If the remainder of the coal now believed recoverable by strip mining is removed, this will involve 71,000 mi^2, or an area about the size of Pennsylvania and West Virginia.

Particularly in Appalachia, the coal strip-mining problem involves large acreages of land which were mined many years ago. Some are now severely eroded and barren of vegetation. In other areas, reclamation has resulted in landscapes which detract from esthetic value because of the poor quality vegetation. The more recently mined areas are somewhat easier to revegetate, since State regulations usually require that the more toxic overburden be buried and at least some natural top soil be spread over the surface.

The Department of Agriculture has been concerned for many years with revegetation of disturbed lands (16). It has been an essential part of their soil and water conservation techniques. Research on coal strip-mined lands began in 1966 with greenhouse studies and in 1970 with field studies in West Virginia and North Dakota. Highest priorities were placed on plant species needed to establish and maintain a desirable vegetative cover and to developing the best suited cultural and management practices. Presently, there is emphasis on characterization of the chemical and physical properties of the overburden before mining so it can be effectively segregated and utilized in the reclamation process. In Appalachia neutralizing material are sufficient in some locations so blending seems to be a better means of preventing acidity problems than the more common practice of deep burial of the most acid spoil portion (17).

Another aspect of the strip mining problem is its alteration of the area's hydrology and of sediment yield. Very often, strip mining can unfavorably change the hydrologic characteristics which results in greatly increased runoff, erosion, and sediment production. Aside from revegetation aspects of reclamation, possible topographic modifications to provide more desirable hydrologic characteristics of the spoil area must be considered. In the past little attention has been given to this phase of the problem, but currently some projects are being initiated.

Recent research by the Agricultural Research Service, USDA, and cooperators in Appalachia indicate (a) forage yields on reclaimed spoils are highest when rock phosphate is applied, (b) Bermudagrass has promise for revegetation if phosphorous and nitrogen deficiencies, as well as acidity, are corrected, (c) crown vetch can be established, if weeping lovegrass is used first as a cover crop, and (d) composted sewage sludge is a promising soil treatment. Currently, in West Virginia and Maryland, about 3,000 plots are involved in the revegetation studies. Our scientists are concerned also with (a) deep placement of fertilizer, (b) evaluating Rhizobium inoculants, (c) plant survival on outer slopes, (d) element uptake by various plant species, and (e) using sewage sludge as a soil amendment. ARS scientists (18) concluded that acid mine spoils in Appalachia could be altered in a relatively short time, to have good production potential. They believe that physical structure, involving available soil water and stoniness, is the most difficult to improve.

In the northern Great Plains progress has been made in identifying factors which hinder reclamation and revegetation of strip-mine lands (19). Phosphorous is always deficient, but readily corrected by fertilization. In North Dakota spoils originating from deeper than about 15 m are frequently high in absorbed sodium and clay content. The highly sodic spoils are impractical to reclaim because of water shortages. A series of plots were established recently which will be used to evaluate the succession of native grass species on spoils with and without top soil at various depths. Experimental results indicated considerable benefit from surface application of as little as 5 cm of natural top soil over the sodic materials. In Wyoming, new revegetation trials were established at three mine sites. For these sites a broad range of woody plant species were obtained for the revegetation trials from several sources, including the Soil Conservation Service and Federal and State Forest Service nurseries. Because the northern Great Plains is semi-arid, the management of all aspects of water availability to plants is very important.

The Cooperative State Research Service and the State Experiment Stations of 12 coal-producing States have developed projects concerning a wide range of terrestrial environmental problems related to strip mining of coal. Most of these projects deal with revegetation of reclaimed lands. One project will investigate the effects of SO_2 pollution on native plants and crops.

The Forest Service has developed a surface environment and mining program (SEAM). Besides the several research projects already identified, they have projects on utilizing remote sensing techniques, on establishing microbial populations in sterile soils, on plant resistance to drought stress, on improved stability of mine spoils, and on evaluating strip mining effects on wildlife.

The Soil Conservation Service has maintained a National Plant Materials Center at Beltsville, Maryland, since 1938 (20), which has focused on determining plants most useful in conservation. In the past decade, more effort has been devoted to finding plant materials useful for stabilizing surface-mined coal fields, especially in Kentucky and Wyoming. Work currently is in progress on a report of plant materials as related to reclamation of surface-mined lands. Also, it will be working jointly with four other USDA agencies in preparing a USDA technical handbook. Other projects being initiated or accelerated are (a) selecting quality plants, (b) plant propagation techniques, (c) cultural and management techniques to maintain vegetative cover, and (d) encouraging commercial production of seeds and plants for mine land reclamation.

Future Projection

Future research will try to define the chemical and physical properties of the overburden for several coal-producing areas, determine the depth of top soil material which should be replaced to achieve satisfactory production levels for various plant species, and develop suitable techniques to reclaim lands so that these areas are at least as productive as they were originally.

Because research on reclamation also may indicate a need of changing some mining methods, research information must be available as soon as possible. By 1985, massive expenditures in equipment and mine development are anticipated that will make increasingly expensive further alterations of mining operations only to facilitate land reclamation.

SUMMARY

The major primary pollutants from coal-burning power plants are SO_2, NO, NO_2, acid aerosols, ethylene, and heavy metals, like lead, cadmium, and zinc. The NO_2 and certain reactive hydrocarbons also may participate in photochemical reactions which generate toxic secondary pollutants, especially ozone. Mixtures of O_3 and SO_2, NO_2 and SO_2, and SO_2 and cadmium have shown synergistic effects under laboratory conditions. Open-top chambers can be used to assess the effects on crop productivity of low levels of pollutants. Protective chemicals, like benomyl, also may be valuable in studying the effects of oxidants. One field study of SO_2 injury showed that soybean plants, visibly injured before blooming, apparently recovered sufficiently so that their yield was not affected. Concern is widespread over effects of acidic precipitation on agriculture and forestry.

Most of the new research and development projects on revegetation of coal strip-mined lands are too new to yield results. We may anticipate that reclamation planning will be an integral part of surface coal mining operations, like those described recently in West Germany (21). A systems approach is developing which accounts for (a) land use options, (b) chemical and physical properties of the overburden, (c) mining methods that optimize separation according to quality, and the subsequent use of the overburden, (d) kinds and amounts of fertilizer and other soil amendments to use, (e) best management practices, and (f) best plant material to achieve intended land use. In addition to their use in agriculture and forestry, strip-mined areas can be used at some locations as parks, airports, sites for building schools or some types of industries, or even new towns or lakes (21).

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DISCUSSION ON TERRESTRIAL EFFECTS SESSION

Comment from the Floor: At the present time, there are 30 identified investigations in the coal strip area, sponsored by EPA and ERDA, which will employ cooperative field techniques. These cooperative field techniques are intended to reduce the capacity for redundancy of effort. This coordination is of considerable interest to the State of Montana's Lieutenant Governor's Office.

Panel Response: The size of the scientific effort in the coal strip area requires careful coordination to avoid both redundancy and to prevent interference between various field study plots.

Question: There has been some reference to Western coals as clean. Does this reference refer to the ash content or trace element content, or is it made on a comparative basis with Eastern coals on a BTU basis?

Panel Response: No, the reference to "clean" was intended to mean relatively clean. Western coal has very high ash, low BTU and in several cases less than 6 to 7% sulfur. There are also some constituents such as fluoride. These coals are relatively clean as compared to some mid-Western coals and possibly some Eastern coals as well.

Question: Some of the proceeding program descriptions have an element of optimism as opposed to pessimism. Some beneficial results have been described from SO_x, and there has been reference to the possibility of spraying to reduce the damaging effects of some pollutants on plant life. Would the panel comment on this.

Panel Response: Sulfur and other matter is essential to plant growth. Plants require as much sulfur as phosphorus which is regarded as a primary nutrient. In the past, it has been the practice to fertilize both materials containing considerable amounts of sulfur. Today's fertilizers generally do not include sulfur, particularly in the Southeast because of the amounts deposited to the ground from atmospheric contributions. The amount of sulfur being added to soils with rainfall can be measured, but the amount of sulfur added in gaseous form is unknown. A total amount of sulfur added to the soils should be accurately established.

Question: Does the sulfur and sulfur compounds additions result in a progressively increasing acidity of the soils?

Panel Response: This question of increased acidity of the soils has not been determined. This is another area that requires investigation.

Question: Current studies seem restricted to short-range studies on the effects of pollutants on plants. Are there any strategies to develop programs and support studies on the effects of long-range repeated exposure?

Panel Response: Both EPA and the U.S. Department of Agriculture have five-year programs funded which would permit long-range low-level, chronic exposure studies.

Comment from the Floor: In the West particularly, transport of sulfate from power plants will take place over distances as great as 100 miles. Resultant deposition will fall on plants, not only the soil. In the semi-arid plains, some species such as the Ponderosa Pine are very sensitive to sulfur, especially when exposure has not occurred previously. Sulfur landing on grazing lands is ingested by wildlife and livestock. In addition, other concerns are of fluoride as a synergistic impact.

Question: Is it basically true that an increase in soil acidity will also increase the availability of other nutrients such as phosphorus?

Panel Response: No, increase in soil acidity generally has the opposite effect. Lime will counteract this soil acidity on the surface. However, surface liming does not solve the problem of acid subsoils.

Question: Please comment on the use of protective chemicals on plants.

Panel Response: Some fungicides will, as an example, protect tobacco from oxidents. The effects of protective chemicals on yields of various cultivars differs as does the degree of injury protection afforded. There is work in this field being pursued now. This includes addition of protective chemicals to the soil that will be taken up by the plants. Work in this field would benefit from better measurement tools and techniques. Consequently, the potential threat of sulfur on the ecosystem should not be discounted.

Comment from the Floor: There is a need to make the results of research available to the people who can use the information. One recent development is the Interview Research Information System which is a part of the SEAS Program. Another, the Old West Regional Commission operates a computer system listing ongoing research studies. A system called SEAS Info provides description of EPA reports. It is expected that these information systems may be of interest to the group.

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CHAPTER 8
ENERGY RESOURCE EXTRACTION

INTRODUCTION

The Nation's demand for energy self-sufficiency will result in an increasing amount of land disturbed by the extractive process.

With oil and gas no longer plentiful, coal has become the mainstay of Project Independence to make the United States energy self-sufficient. To achieve this goal, the low sulfur coal lying close to the ground surface in the West must be developed. In addition, continued exploitation of eastern coal regions will be necessary with surface and underground mining.

For the foreseeable future, coal can be expected to provide the bulk of domestic augmentation replacing foreign energy sources. However, until gasification and liquefaction techniques are perfected and implemented, there will be a continued dependence on fuels derived from natural hydrocarbons. The requirements for these fuels is likely to persist, especially in transportation. Consequently, there will be added impetus for gas and oil exploration. This exploration will extend to remote and relatively inhospitable regions. Even with increased domestic production and moderating increases in demand, some shortfall will exist. The large reserves represented by the oil shale deposits in the Upper Colorado River Basin make this source a likely candidate, if the necessary technology is available.

Each of these extractive processes has its unique environmental price.

Underground mines present one of the most difficult environmental problems. Damage may result from acid mine drainage, subsidence or sedimentation. Environmental implications of the methane emissions accompanying underground mining are not well understood. Successful closure techniques are yet to be perfected.

Surface mining disturbs large areas, frequently in rural, range, forest or farm areas. During the next decade, disruption will approach one quarter of a million acres annually. Without reclamation, there is both loss of land use and ecological damage. Great strides have been made in the development of reclamation techniques. These techniques have been developed mainly as a result of experience with surface mining in the East. Reclamation of disturbed Western areas will pose severe new problems because of the arid character of the region. Reclamation of land disturbed in mining of oil shale will present additional problems associated with disposition of very large volumes of spent shale.

The environmental price of oil and gas extraction is largely associated with spillage and the consequential contribution of human activity at the drilling sites and along the routes of transport. Environmental consequences may be aggravated by the ecological fragility of the areas developed, such as the Alaskan tundra.

Energy resource extraction is inherently a disruptive process. Protective emphasis is being placed on minimizing the initial extractive damage followed by restoration aimed at reducing the residual damage. The burden of developing the necessary technologies is shared by federal, state and local agencies as well as the private sector.

ENVIRONMENTAL ASSESSMENT OF WESTERN COAL SURFACE MINING

Elmore C. Grim
Surface Mining Specialist
Extraction Technology Branch
Resource Extraction and Handling Division
Industrial Environmental Research Laboratory
Cincinnati, Ohio

Recent oil and gas shortages in the United States have focused the Nation's attention on supply and demand problems associated with what is popularly called an energy "crisis". There is increasing interest in developing a higher degree of independence from foreign energy supplies, primarily oil and oil by-products.

The President's 1973 energy message encouraged the use of domestic coal to meet the needs for energy. Since low sulfur coal lying in close proximity to the ground surface is economically attractive to energy producers, much of the near-surface coal resources in the West are important. This emphasis on use of western coals has been reiterated by private and Federal sectors with increasing frequency.

According to U.S. Bureau of Mines estimates, the western coal fields contain more than 60% of the strippable coal reserves in America. It has been estimated by the Federal Government that in 1985, 1.2 billion tons of coal must be mined to meet the demand in the industrial, power generation, synthetic gas, and export sectors of the market. This amount will double the coal production of 600 million tons for last year. To achieve a total production of 1.2 billion tons, at least 350 million tons will have to come from western coal fields to supplement the 850 million tons derived from the traditional coal-producing region's of the East and Midwest. Comparing that figure with last year's production from western states of approximately 60 million tons, one begins to grasp the scope of potential coal development in this area of the nation. Although characterized by low BTU and high ash content, western coal contains very little sulfur, and the large size of the coal fields make them attractive to the huge industrial plants that result from future growth i.e., gasification and liquefaction processes.

The adverse impacts of coal mining in the eastern United States have been well documented and intensively researched. Relatively little is known concerning the potential degradation that may result from large scale mining in the arid West. A better definition of the type and magnitude of potential environmental problems is required.

Suspected water pollution problems are: (1) salinity, (2) sediment, and (3) ground water disturbance. Preliminary results indicate that salinity discharges as high as 23kg per cubic meter of spoils can be produced. The salinity potential for western coal mines needs to be well defined and a method developed to predict the magnitude of the problem before mining.

Coal seams are generally aquifers, and are a principle source of fresh water. Mining may result in alteration of ground water distribution by aquifer disruption. It will be necessary to verify the magnitude of the aquifer disruption problem and quantify its effects on groundwater quality and quanity. In addition, if solid wastes from power plants, gasification plants, etc., are to be returned to surface mines where aquifers were present, a potential groundwater pollution problem may exist.

Western overburden material is of young geologic age and subject to excessive erosion. Stabilization of the spoil, as quickly as possible after grading, is required to minimize sediment discharges. Flash flooding and wind erosion constitute major hazards in damaging soil loss. Possible air pollution problems involve fugitive dust from extraction, loading, hauling, and support facilities. In addition, emissions from spontaneous combustion of coal seams and waste materials causes considerable air quality degradation. Work is planned to assess the magnitude and significance of these air pollutants.

One of the major drawbacks to western reclamation is revegetation. Climatic conditions are extreme. Seventy-five percent of the western coal fields receive less than twenty inches of annual precipitation available for plant growth. In addition to limited precipitation, seasonal temperatures vary from -60° to 120° F, only short frost-free periods are available, wide variations are present in overburden material, and adequate topsoil is lacking.

Water is the key to any successful reclamation program in the West. Ample moisture at planting and during establishment is critical. Techniques for acquiring additional moisture need to be developed. This should include studies on surface manipulation, irrigation, mulching, etc., and the impact of these practices on surface and groundwater quanity and quality.

Only by pre-mining planning is it possible to eliminate irreversible mistakes. Planning investigations include range inventories, soil surveys, grazing pattern definition, watershed surface and groundwater studies, archeological review and overburden analyses. These studies serve as a base for planning spoil segregation, rehabilitation design, erosion control, surface manipulation, topsoiling and range management. These accomplishments directly affect the mining techniques and equipment used. They also allow most problems of extraction and rehabilitation to be predictable.

The people of the West generally express concern over expanded extraction in terms of their own occupational interests. Many ranchers and farmers are worried about competition for land and water, and about the conversion of present and potential agricultural water supplies to industrial usage. Some believe that mined land cannot be reclaimed nor shallow aquifers rebuilt. A general concern shared by most people is the impact of air pollution on range vegetation, crops, and abundant wildlife resources. The several Indian tribes in the region are concerned over the impact of coal development on or near their reservations in terms of water rights, resources and cultural values.

Not everyone is fearful about the effects of developing the coal. There are people who view the development as something good. They see increasing coal development in terms of an expanding economic base, new jobs, better services and a chance to broaden cultural horizons.

Offsetting this rather gloomy picture, however, is a general (although cautious) optimism that the environmental impacts of western strip mining, both during and after mining, can be reduced to "acceptable" levels if suitable planning and operating technologies are brought to bear. In short, mined lands can be reclaimed. Reclamation as an add-on technology will no longer suffice. Rather, as has been noted by EPA researchers, environmental factors must be considered from the word "go" (during pre-mining planning); reclamation must be an integral part of the mining process. This fact manifests the realization that the environment is best protected by designing (and using) new mining technologies (methods and equipment) which consider reclamation objectives as well as production goals. Of course, such technologies cannot be developed solely by mining engineers nor solely by geologists, hydrologists and agricultural scientists. Instead, an interdisciplinary approach is necessary. EPA recognizes this need and has initiated a Federal interagency energy/environment R&D program. Regularly scheduled meetings are held with EPA's research personnel, other EPA officials and representatives of other agencies involved in related research to ensure that the research needs in each problem area are adequately covered. Contract, grants and interagency agreements have been negotiated for most of the projects in EPA's current R&D program.

Interagency agreements, formulated for implementing research projects, are being funded by "pass-through" of $1.44 million for FY75 and $1.7 million for FY76 from the energy R&D budget.

Interagency agreement projects are as follows:

1. Western Coal and Oil Shale Mining: Vegetative Methods and Materials - USDA.
   Objective Summary: Technical handbooks for vegetating western coal and oil shale mines in arid and semi-arid areas are being prepared. These handbooks will be directly used by mine operators and regulatory agencies and also by planning and impact analysis agencies. The books will include recommendations of plant species, methods of planting, soil amendments, seed sources, seed bed preparation, etc.
2. Surface Manipulations for Enhanced Coal and Oil Shale Mine Vegetation USDA. A. Wastes for Soil Amendments, B. Growth Supporting Media.
   Objective Summary
   - A. Evaluation is being made of non-mine waste materials (such as sewage sludge, woodchips, straw, solid waste, food processing wastes) as soil amendments in reclaiming surface mines.
   - B. Scientific criteria are being developed to recommend guidelines for determing quantity and quality of growth supporting media (topsoil) for coal and oil shale reclamation.

Contracts and grants have been developed for implementing research projects. These are being funded from the energy R&D budget in the amounts of $1.751 million for FY75 and $1,080 million for FY76.

Contract work is as follows:

1. Environmental Impact of Western Coal Mines - Contractor; Mathematica, Inc.
   Objective Summary: This project is specifically designed to evaluate the surface mining methods presently employed in the mining of the western coals in arid and semi-arid regions, and to evaluate the effects these methods have on the environment.

Grant work is as follows:

1. Effects of Surface Configuration in Water Pollution Control - Grantee; Montana State University.
   Objective Summary: Objectives of this study are to demonstrate the effectiveness of several surface configurations in controlling erosion, runoff, sedimentation and pollution of adjacent drainages, quickly producing a desirable stabilizing vegetative cover, creating an equilibrium between precipitation absorbed and soil moisture evaporated and transpired so that ground water pollution will remain minimal, and producing an overall desirable reclamation design providing effective drainage, esthetics, productiveness and use. Surface water and groundwater is being monitored extensively at the five test sites in Montana, Wyoming, and North Dakota.
2. Surface and Subsurface Water Quality Hydrology - Grantee; Colorado State University.
   Objective Summary: This project is to develop a mathematical model capable of predicting the quantity of surface and subsurface flow on surface mine spoils in the Rocky

Mountain Region. This objective will be accomplished by modifying and interfacing existing models of subsurface chemical transport, certain geochemical reactions, overland flow on infiltrating surfaces, and sediment transport. A current study has identified the important physical and chemical characteristics of the spoils which must be included in the model. The adequacy of the model will be thoroughly tested on field plots located on coal mine spoils in Colorado.

3. Northern Cheyenne Tribal Council project, Montana - Grantee; Northern Cheyenne Tribal Council. Objective Summary: The Northern Cheyenne Tribe, via the Northern Cheyenne Research Project, desires to develop an in-depth knowledge of the chemical character of reservation water resources, and the interrelation of water to other resources, so that the Tribe can make informed choices in planning coal development. Environmental base line data is being collected for future reference when mining begins. This project will provide an additional data source for the following project.
4. Evaluation of Surface and Groundwater at Potential Strip Mines - Grantee; Montana State University. Objective Summary: The major objective of this project is to identify possible impacts of coal mining and development in the Northern Great Plains on the surface and groundwater systems of the surrounding area. Specific objectives are: 1. Obtain an equation of balance for all water inflow and outflow in each of three study sites, one each in Montana, North Dakota, and Wyoming; 2. Characterize the overburden from a physical and chemical point of view as well as determine its relationship to the water coming to the surface; 3. Characterize the chemical features of the mined sites; and 4. Determine hydrologic character of spoils at active mine sites in Montana.

In Table I below, the resources being expended on western coal projects are summarized.

TABLE I
RESOURCES EXPENDED ON WESTERN COAL SURFACE MINING

	FY75		FY76	
Expendature	Projects	$K	Projects	$K
EPA				
Contract	1	173	1	0
Grant	4	1,578	4	1,080
USDA				
IAG*	3	1,440	3	1,700
TOTAL	8	3,191	8	2,780

*Funding is for combination of Coal and Oil Shale projects.

EPA's role is not to develop new surface mining technology. However, in cooperation with the U. S. Bureau of Mines and others, we are planning to contribute to the development of these new methods from the standpoint of environmental impact.

As trends develop in more sophisticated underground mining methods, we will initiate environmental control projects to keep abreast of the effects of these technological developments.

Most R&D efforts at this time are aimed at pinpointing problem areas. This assessment phase will be followed by comprehensive R&D efforts to demonstrate techniques which minimize adverse environmental effects. The ultimate goal is to publish Manuals of Practice to outline the most current and acceptable technology for all phases of mining that have a detrimental impact on the environment. Training programs for mining personnel and state and federal control agencies are also planned as goals.

ENVIRONMENTAL CONTROL TECHNOLOGY OF EASTERN COAL DEVELOPMENT

Ronald D. Hill
Director
Resource Extraction and Handling Division
Industrial Environmental Research Laboratory
Cincinnati, Ohio

INTRODUCTION

For discussion purposes during this symposium, the coal fields of the United States have been divided into the eastern and western. A better definition of these fields would be humid vs arid/semi-arid regions. The production and number of mines for each region is shown in Table 1.

Table 1

NUMBER AND COAL MINE PRODUCTION 1973

	Eastern U.S.	Western U.S.*
Total Production, Million Tons/Percent	523 / 91	51 / 9
Surface Mine Production, Million Tons/Percent	212 / 82	46 / 18
Total Mines, Number/Percent	1,726 / 97	52 / 3
Surface Mines, Number/Percent	873 / 96	34 / 4
Underground Mine, Number/Percent	853 / 98	18 / 2

*Arizona, Colorado, Montana, North Dakota, New Mexico, and Wyoming.

As demonstrated in this table the eastern fields dominate the coal industry both in production from surface and underground mines and number of mines. As the United States strives toward its coal production goal of 1.2 billion tons per year, the western fields will assume a larger share. However, significant increases in eastern production and number of mines will also occur.

The environmental damages from past and present eastern surface mining has been documented. Over 10,000 miles of streams have been degraded by acid mine drainage. Sediment clogged streams are common. Fugitive dust is emitted from mines and haul roads. Mining has a unique feature in that environmental damages continue even after mining ceases because acid production and erosion are natural phenomena which are accelerated by man's activities. Thus, the environmental damages from past mining activities exceed that from current ones. Mines must be closed properly to prevent pollution in the future.

Great strides have been made in the past ten years to reduce the environmental damages from surface mines. All of the major eastern coal producing states now have laws controlling surface mines. The effectiveness of these laws depends upon the provisions of the law, the regulations and the capabilities of the state enforcement agency. In general, the laws require a permit to mine, performance bonds, backfilling of pit, grading of spoil and revegetation of the disturbed area. Strong environmental concern by the public has led to the development of new mining methods and reclamation techniques by the industry. These new methods and techniques have significantly reduced acid mine drainage and improved the sediment problem. However, erosion, by both air and water, is still a cause of environmental damage.

Environmental damages resulting from underground mines include: acid mine drainage, subsidence, and sediment from surface facilities. During active operation the water discharged from an underground mine can be treated to meet the effluent guidelines proposed by EPA. The major environmental damage occurs when the mine becomes inactive and a responsible party to treat the water is unavailable. The environmental implication of the over 227 million cubic feet per day of methane emitted is unknown. Control of the dust and silt from surface facilities is limited.

SURFACE MINING PROGRAM

EPA(1) has recently completed a comprehensive review of the surface mine industry. It can be concluded from this report that a large store house of knowledge has been developed by federal, state, and industrial groups on the reclamation of surface mines. It was felt that the time had come to prepare a set of comprehensive "how to" manuals for use by industry, and state and federal control agencies. Contracts, grants and interagency agreements were developed to prepare the following manuals: (1) Paleoenvironment analysis as a predictor of acid mine drainage, (2) Field and laboratory methods applicable to overburdens and minesoils, (3) Manual to control sediment and erosion during mining, (4) Revegetation manual, and (5) Predictive and pollution abatement model for mine drainage. Although each of these manuals will be prepared to stand alone, they will become an integral part of a comprehensive manual on premining planning for environmental control of surface mines to be prepared by Pennsylvania State University. The original five manuals will be completed during 1976 and the premining planning manual by July 1977. It is proposed to use these manuals to prepare training courses to transfer the information to the working level, e.g., mine superintendents and surface mine inspectors. This effort is planned to start in FY 77.

Several new mining and reclamation methods have been developed in the past few years with picturesque names such as head-of-hollow fill, mountain-top removal and haul back. These second generation methods have been proclaimed as techniques that will minimize the environmental problems in surface mining. EPA has initiated a program to assess the environmental consequences of these mining methods. Mining operations of several companies will be extensively evaluated and monitored for air and water emissions. Close coordination with the U. S. Bureau of Mines, T.V.A., and the U. S. Forest Service, who are working on the development of new mining methods, will be maintained. Future research and development by EPA will depend on the outcome of these assessments.

One of the major unresolved environmental problems associated with surface mining is sediment. The primary sediment control method in many states is the sediment pond. A study has been completed for EPA which reported that there are shortcomings in the present design, operation, maintenance and closure of sediment pond. EPA is initiating an inhouse research program at its West Virginia research station and a demonstration project in cooperation with the Commonwealth of Kentucky to develop better design criteria for sediment ponds.

Haul roads are often a significant source of dust and sediment. EPA in cooperation with the Commonwealth of Kentucky has begun a project to demonstrate improved haul road construction methods. Discussions have been held with the U. S. Bureau of Mines to also take part in the project.

EPA through interagency agreements with USDA, T.V.A., and ERDA supports work on developing revegetation methods for surface mines, evaluating damages from surface mines and utilization of waste products to reclaim mines.

UNDERGROUND MINING PROGRAM

The control of water pollution from underground mines is one of our most difficult problems. Although the discharge can be treated while the mine is active, upon mine closure treatment became uneconomical. We feel the answer to this problem is the development of new mining methods that will minimize the discharge upon mine closure. A recent study for EPA showed that mining to the down-dip had definite environmental advantages. The University of Alabama is currently evaluating mining methods that might prevent water pollution. We plan to pursue an aggressive program in this area.

EPA has an active program in developing technology for dewatering (prevention of water from entering the mine) underground mines. Current projects include evaluating methods of locating sources of water that enter a mine and pilot studies on dewatering both an active and inactive mine. If found feasible we hope to proceed to a full scale demonstration in cooperation with the Bureau of Mines and industry. This work might fit closely with the Bureau's methane drainage program.

Stowing in underground mines for subsidence control and waste disposal has been evaluated by National Academy of Science and although found technically feasible was economically questionable. EPA in a joint venture with the Commonwealth of Pennsylvania and in cooperation with the Bureau of Mines is evaluating the concept of stowing waste (fly ash, and SO_x sludge) in underground mines to prevent acid mine drainage. If found feasible we would hope to proceed to a full scale demonstration.

EPA has been active for a number of years in the development of mine seals. We have a continuing effort in evaluating seal performance. Because of the importance of closure methods an intensive assessment of closure methods is currently being conducted for EPA. The results of this study will be used to develop our Research and Development program in this area.

Two additional assessment studies are planned. The first will assess the consequence of groundwater as a result of underground mining. The second will assess air emissions from underground mines and their support facilities. Future research efforts will depend on the results of these studies.

TREATMENT OF MINE DRAINAGE PROGRAM

Since 1967 EPA has been evaluating numerous schemes for treating acid mine drainage (AMD). At this time neutralization is the accepted method. EPA's recent efforts have been to improve the efficiency, reduce the cost and develop sludge disposal methods. These are inhouse efforts conducted at our West Virginia field site. This work should be concluded in the near future.

Since neutralization does not usually decrease the total dissolved solids (TDS) content and often a water is produced that is unsuitable for many uses, we have been evaluating two methods that remove TDS, i.e., reverse osmosis and ion exchange. During 1976 a manual of practice for utilizing reverse osmosis for testing AMD will be produced. We are in the pilot plant stage in our ion exchange studies.

SUMMARY

In Table 2, the resources being expended on eastern coal mining are summarized.

Table 2

RESOURCES EXPENDED ON EASTERN COAL MINING

	FY 75		FY 76	
	No. Projects	$K	No. Projects	$K
Surface Mines				
EPA	21	1500	25	800
IAG	-	170	-	175
Underground Mines	16	1300	18	280
Treatment	8	300	7	276

REFERENCE

Grim, E. C., and Hill, R. D., "Environmental Protection in Surface Mining of Coal," EPA Publication 670/2-74-093, Cincinnati, Ohio, October 1974.

USDA RESEARCH AND DEVELOPMENT FOR RECLAMATION OF LANDS AFFECTED BY MINING 1/ 2/

David J. Ward
Research Planning and Coordination
USDA, Office of the Secretary
Washington, D.C.

BACKGROUND

The Nation's demand for mineral resources and energy self-sufficiency will result in an increasing amount of land disturbed by mining and mineral processing. An estimated 4.4 million acres of land have already been disturbed by mining. About 1.9 million acres (including 100,000 acres of National Forest System lands) remain to be reclaimed. Added to this, nearly 200,000 acres may be disturbed annually during the next decade. By 1990 the rate of disturbance may reach 250,000 acres per year. Some projections indicate that as much as 12-13 million acres may eventually be disturbed.

Surface and subsurface mining of fossil fuels and minerals, and related activities such as coal gasification, oil shale processing, ore reduction and transport of mined commodities create strains on the Nation's food and fiber production base, the environment, and rural communities. Forest lands of the east, grasslands and croplands of the midwest, and rangelands of the Northern Great Plains and elsewhere in the West are underlain by vast coal resources and other minerals that can be surface mined. The potential for destruction of surface values on these and other rural lands is great.

Without proper planning and reclamation, serious impacts can be expected on agricultural production, environmental quality and rural communities. These impacts will affect not only mined areas, but will have deleterious effects on surrounding areas and non-mining sectors of the economy.

Since most mineral development takes place in rural America on range, forest, and farm lands it is the responsibility of the Department of Agriculture to see that the technology and technical assistance is adequate and effective for reclamation of mined lands and that social, environmental, and economic impacts of mining are ameliorated. In recognition of this there has been established a USDA Program for Reclamation of Lands Affected by Mining. The Program is concerned with anticipating and ameliorating the effects of fossil fuel and mineral development on the environment, surface resources, people and agricultural production. It coordinates and maximizes the impact of USDA agency activities, thus enabling the Department to exercise federal leadership in reclaiming private and public lands. It also fosters coordination and seeks to avoid duplication with related work of non-USDA agencies.

The Program coordinates and accelerates the individual efforts of several USDA agencies. These agencies are: the Agricultural Stabilization and Conservation Service(ASCS), Agricultural Research Service (ARS), Cooperative State Research Service (CSRS), Economic Research Service (ERS), Extension Service (ES), Forest Service (FS) and the Soil Conservation Service (SCS). They are the ones in USDA that conduct programs directly concerned with the management of soil, water, plants and animals on rural private and public lands affected by mining.

This paper addresses itself principally to a brief description of the research and development aspects of the Program.

PROGRAM GOAL, OBJECTIVES AND BENEFITS

The ultimate goal of the R&D aspects of the USDA Program for Reclamation of Lands Affected by Mining is to provide new knowledge and technology to assure that the Nation's energy and mineral needs are met in a reasoned, selective and orderly way, without sacrificing food and fiber, quality of living in rural areas, or quality of the environment.

Overall Program objectives will be accomplished by assessing potential impacts of mineral development and by developing planning and reclamation technologies and passing them on to users. The technologies derived will apply to private lands under individual or corporate ownership and to public lands, including Federal lands administered by USDA and other Departments. They will also assist local communities, families, and firms affected by industrialization.

Included among the objectives are:

Land - As many as 12 or 13 million acres of land may be disturbed by 1990. Disturbance patterns and reclamation potentials will be identified in advance of mining. This will make it possible to plan development activities so that land critically needed for producing food and fiber is not taken out of production. Land that cannot be reclaimed for present use or returned to more productive uses will be identified so that appropriate public action can be considered. Technology will be developed and disseminated and technical assistance will be provided so that the private sector can effectively reclaim mined lands.

1/ This paper is largely based on materials prepared by a USDA interagency work group.

2/ USDA has a long history of cooperative activities with research arms of Land Grant Colleges and Universities. In addition to research and development conducted by USDA, the R&D described in this paper includes research conducted by the State Experiment Station System with funds (1) initially appropriated to USDA or (2) "passed through" to USDA from EPA.

Water Use - Many mining, transportation, and conversion technologies require large quantities of water. It is expected that a significant portion of the mineral development activities will occur in water-scarce areas. Thus water could be diverted from agricultural and other uses to mineral development uses. Through the Program, water demands will be identified and adverse impacts assessed. To the extent possible, mineral development activities can then be planned, phased, and located so that agricultural productivity will not be seriously affected.

Water Quality - Some mineral development activities can result in degraded water quality both through consumption and the discharge of pollutants into water supplies. For example, disturbance of the soil profile by surface mining can increase the movement of soluble salts and acid-forming materials into the surface and groundwaters. Technologies developed through the Program will often prevent degradation of water quality. Situations where control technologies are not feasible will be identified so that mineral development may be avoided.

Air Quality - The discharge of toxic gases and particulate materials from mineral processing activities may affect growth of vegetation and productive capacity of surrounding areas. This adverse impact will be reduced through the development of toxic resistant plant varieties or the identification of situations where compensating actions are needed.

Maintaining and Promoting Viable Rural Communities and Areas - Rural communities and areas will be provided with information and alternatives to adjust governmental organizations, educational systems, permanent resources, and public and private services needed to accommodate increasing populations. Without prior knowledge of expected impacts and mechanisms to deal with these impacts, overcrowded schools, shortages of capital and consumer goods, inadequate public and private services including sewage, roads, medical, etc., and localized inflation will result. The Program will provide means to promote orderly economic growth in rural areas in order to capture the benefit both of rural living and strong economic growth.

Agricultural and Forest Productivity - The Program will diminish the possibilities for long-run losses of productive capacity of U.S. agriculture as a result of mineral development and associated transportation and processing. For example, in the States of Montana, Wyoming, and North Dakota alone the annual value of production of wheat, barley, and oats potentially displaced annually by mining has been estimated to be as much as $2 million at current prices. Without reclamation these losses would continue over time. Losses can be avoided by identifying and taking measures to prevent critically needed land areas from being taken or removed from production, by ensuring that adequate quality water supplies are retained, and by taking action to compensate for the release of toxic matter into the air.

Environmental Amenities - Land reclaimed in accordance with plans made prior to mining can provide multiple use benefits. Planning can lead to development of improved wildlife habitat, of new water based recreation opportunities such as swimming and fishing, and provide for other recreation activities.

FIELD UNITS IMPLEMENTING THE PROGRAM

The overall Program is implemented by several organizations working at many locations. General information about these arrangements, including information about how survey, education, technical assistance and reclamation activities interrelate with the research and development program are given below.

Activity, Scope and Extent

R&D - 20 USDA field research centers in 16 States. Research agreements with 11 Universities. Research projects at 18 State Agricultural Experiment Stations. Plant Materials development at 14 Plant Materials Centers and 2 Forest Nurseries. Mining and reclamation demonstrations in 4 States.

Surveys - Soil survey teams active in 652 counties where major mining impacts are anticipated.

Education - Extension specialists active in 28 states disseminating reclamation information. (There are over 3,000 Extension offices nationwide.)

Technical Assistance - Technical assistance provided to more than 22,500 landowners and mining companies in approximately 2,000 counties, through Conservation Districts and State and Private Forestry Programs.

Reclamation - Reclamation projects on orphaned or abandoned mined lands on National Forests and Grasslands in 5 states.

R&D COMPONENTS OF THE PROGRAM

The general nature of the R&D Aspects of the Program is outlined below. These activities are carried out with (1) funds appropriated to USDA, (2) energy R&D funds "passed through" to USDA from EPA and (3) funds transferred to USDA by the Bureau of Mines, USDI.

R&D Aspects of the USDA
Program for Reclamation of
Lands Affected by Mining

1. Impacts of alternative mineral extraction methods, related transportation systems, and industrial plants processing mined material.

   a. Production of food and fiber and on surface resources
   b. Groundwater
   c. Wildlife and fish habitat
   d. Aesthetics
   e. Employment, living standards, and structure of local rural areas and communities
   f. Interregional shifts in economic activity and local employment
   g. Availability and quality of water for agricultural production

h. State and local governments

2. Reclamation technology

a. Overburden Analysis

1) Core sampling and laboratory procedures
2) Prediction of spoil stability, potential for plant growth, and water quality
3) Methods of overburden handling to prevent interruption of groundwater flow

b. Redeposition

1) Methods of stockpiling and replacing soil
2) Methods of overburden redeposition based on core analysis
3) Methods of redeposition to achieve better spoil stability

c. Hydrology

1) Methods of handling water to prevent erosion and flood damage
2) Methods to improve quality of water flowing from mined lands

d. Amendments

1) Spoil amendments on high alkali and high acid conditions
2) Irrigation as a spoil leaching technique
3) Mulches and fertilizers to aid plant establishment

e. Plant Materials

1) Plant species adaptable to acid spoils and high altitude sites
2) Use of microbiological techniques to assist plant establishment
3) Expansion of plant materials production
4) Vegetation cover for special uses such as wildlife, recreation

f. Cost Effectiveness

Least-cost reclamation technologies that will meet environmental and productivity standards

g. Pilot Testing

1) Field testing on small plots of nursery-grown planting stock
2) Field evaluation of nursery stock on mine sites
3) Field demonstration of the total reclamation process including planning, extraction, and reclamation

h. Systems

1) Storage and retrieval systems for information required in mineral planning and decisionmaking. The system will contain geographically oriented information as well as technological information. The system will provide users with immediate services for long-range or project-specific planning.
2. Analytical procedures for predicting impacts of mining and reclamation under a wide variety of conditions.

As shown below, R&D aspects of the Program are carried out at many places in several physiographic regions of the country.

Location	USDA Agency				
	ARS	CSRS	ERS	FS	SCS
Alabama, Auburn		X			
Arizona, Tucson		X			X
California, Berkeley				X	
Colorado, Ft. Collins	X	X	X	X	
Meeker					X
D.C., Washington			X		
Idaho, Aberdeen					X
Cour de' Alene				X	
Lucky Peak				X	
Moscow		X			
Illinois, Peoria	X				
Urbana		X			
Kansas, Manhattan		X			
Kentucky, Berea				X	
Lexington		X			
Quicksand					X
Maryland, Beltsville	X				X
Michigan, East Lansing		X			X
Missouri, Elsberry					X
Montana, Billings				X	
Bozeman		X	X	X	
Bridger				X	X
Missoula				X	
New Mexico, Albuquerque				X	
Las Cruces		X			
Los Lunas				X	X
New York, Big Flats					X
Ithaca	X				
North Carolina, Raleigh		X			
North Dakota, Bismarck				X	X
Fargo		X	X		
Mandan	X				
Ohio, Columbus	X				
Oregon, Corvallis					X
Pennsylvania, Univ. Park	X	X			
South Dakota, Rapid City				X	
Texas, Knox City					X
Utah, Logan		X		X	
Ogden				X	
Virginia, Blacksburg	X	X			
Washington, Pullman					X
West Virginia, Morgantown	X	X			
Wyoming, Laramie		X		X	

The Northern Great Plains, the Four Corners Area and other parts of the Intermountain Region, the Appalachian Coal Area and the Midwestern Coal Fields are receiving emphasis in the Program. The longest history of R&D activities is in Appalachia. Certain findings from this research are useful in the other geographic areas, but differences in climate, topography, vegetation and a host of other factors require the development of new knowledge and techniques for local conditions.

Roles of USDA agencies in the Program are tabulated below in general terms.

Broad Subject Areas Covered by
Activities of R&D Agencies in the
USDA Program for Reclamation of
Lands Affected by Mining

Subject Area	USDA Agency				
	ARS	CSRS[1]	ERS	FS[2]	SCS
Ecological effects (fresh water)	X	X		X	
Ecological effects (air/terrestrial)	X	X		X	
Overburden analysis	X	X		X	
Redeposition	X	X		X	
Hydrology	X	X		X	
Amendments	X	X		X	
Plant materials	X	X		X	X
Pilot testing	X	X		X	
Modelling and information systems				X	
Integrated assessment		X	X	X	

[1] CSRS supports research and development at State agricultural experiment stations and schools of forestry with (1) funds appropriated to USDA under the terms of the Hatch and McIntire-Stennis Acts and (2) energy funds "passed through" from EPA. The agency does not conduct research.

[2] FS activities are coordinated from Washington, D.C. A significant part of the western R&D is conducted through the SEAM Program headquartered at Billings, Montana. Eastern R&D is largely centered at Berea, Kentucky.

The principal USDA contacts for R&D aspects of the Program are:

Agricultural Research Service

Dr. Harold Barrows
Office of the Administrator
Agricultural Research Service
Room 330A
U. S. Department of Agriculture
Washington, D.C. 20250
202-447-5211

Cooperative State Research Service

Dr. Eilif Miller
Cooperative State Research Service
Room 444W
U. S. Department of Agriculture
Washington, D.C. 20250
202-447-4348

Economic Research Service

Dr. John Schaub
Economic Research Service
U. S. Department of Agriculture
Room 420B
500 12th Street, S.W.
Washington, D.C.
202-447-8735

Forest Service

Dr. Robert Callaham
Forest Service
Room 808 RP-E
U. S. Department of Agriculture
Washington, D.C. 20250
703-235-1071

Soil Conservation Service

Mr. Robert MacLauchlan
Soil Conservation Service
Room 1405P, Auditors Bldg.
U. S. Department of Agriculture
Washington, D.C. 20250
202-447-5667

Office of the Secretary

Dr. David J. Ward
Office of the Secretary
Room 359A
U.S. Department of Agriculture
Washington, D.C. 20250
202-447-3854

These persons comprise a USDA work group to provide broad leadership for R&D aspects of the USDA Program for Reclamation of Lands Affected by Mining.

ENERGY RESOURCE EXTRACTION: OIL AND GAS PRODUCTION

J. Stephen Dorrler
U.S. Environmental Protection Agency
Edison, New Jersey

INTRODUCTION

The extraction, conversion and utilization of oil and gas have played, and will continue to play, a major role in the national energy balance. Recent political and economic developments are expected to spur substantial increases in developing domestic oil and gas resources with the co-commitment potential for adverse impacts on the environment. These developments include:

1. the impetus to markedly increase exploration for, and development of domestic reserves under Project Independence,

2. the expectation that future reserves of oil and gas will be located principally in the outer continental shelf (OSC) regions,

3. frontier areas such as Alaska, heretofore relatively untouched, will experience a major fraction of the new developments,

4. increased market values of oil will result in marked increase in the use of recovery enhancement techniques with, as yet, incompletely understood environmental consequences.

Approximately half a million producing oil wells onshore generate produced water in excess of 10,000,000 barrels per day. Approximately 17,000 wells have been drilled offshore in U.S. waters, and approximately 11,000 are producing oil or gas. Offshore Louisiana, the OCS alone produces approximately 410,000 barrels of water per day;(2) by 1983, coastal Louisiana production will generate an estimated 1.54 million barrels of water per day.(3)

Other than oils, the primary waste constituents from these facilities include oxygen demanding pollutants, heavy metals, toxicants, and dissolved solids contained in drilling muds or produced water. Production wastes include produced waters associated with extracted oil, sand and other solids removed from the produced waters, drainage from the platform or site facilities, sanitary wastes, and domestic wastes. Produced waters generate the greatest concern and can contain oils, toxic metals, and a variety of salts, solids and organic chemicals. The concentration of constituents vary somewhat from one geographical area to another, with the most pronounced variance in chloride levels. Table I shows the waste consituents in offshore Louisiana production facilities in the Gulf of Mexico. Industry data for offshore California describes a broader range of parameters as shown in Table II. Sand and other solids are produced along with the produced water. Although amounts vary, sand has been reported to be produced at approximately one barrel of sand for 2,000 barrels of oil.(2)

Drilling wastes are generally in the form of drill cuttings and mud and are composed of the rock, fines, and liquids contained in the geologic formations that have been drilled through. The two basic classes of drilling muds used today are water based muds and oil muds. In general, much of the mud introduced into the well hole is eventually displaced out of the hole and requires disposal or recovery. Table III provides an estimate of the volume of cuttings and muds in a typical 10,000 ft. drilling operation.

In addition to these chronic type discharges, oil producing and associated facilities also experience oil spill incidents. The U.S. Coast Guard reported 3,644 spills in 1974 from producing facilities. This is approximately 26 percent of the total number of incidents and contributed 3,468,106 gallons of oil to the environment.(4)

EPA's overall program for controlling emissions from oil and gas producing facilities includes work in the following areas:

1. developing technology to prevent environmental damage during the installation and operation of wells, platforms, and transfer facilities,

2. developing criteria to be used in evaluating sites for onshore pipelines and onshore facilities to support offshore oil and gas production operations,

3. developing technology to prevent, control, and cleanup oil spills.

TECHNICAL DISCUSSION

End of pipe treatment technology for produced water from offshore facilities consists primarily of physical chemical methods. Onshore facilities generally practice some form of no discharge treatment such as evaporation or injection into formations. The type of treatment system selected for the particular offshore facility is dependent upon availability of space, waste characteristics, volumes of waste produced, existing discharge limitations, and other local factors. Simple treatment systems may consist of only gravity separation pits without the addition of chemicals, while more complex systems may include surge tanks, clarifiers, coalescers, flotation units, chemical treatment and/or reinjection.

Table IV gives the relative long term performance of existing waste water treatment systems in the Louisiana coastal area. The general superiority of gas flotation units and loose media filters over the other systems is readily apparent. However, individual units of other types of treatment systems have produced comparable effluents.(2)

About 75 percent of the systems in the Gulf of Mexico coastal area are gravity separation systems.

The majority are located onshore and have limited application on offshore platforms because of space limitations.

Despite the fact that the offshore industry has been operating in the Gulf of Mexico since 1954 the waste produced from these facilities has never been adequately characterized. Additionally, treatment technology development has been limited to trial and error using off the shelf oil/water separation equipment. This end - of - pipe treatment approach has never properly addressed upstream control of waste sources. Therefore, EPA is currently sponsoring studies which will define design features of unit processes, equipment and hardware, including pertinent aspects of human factors engineering, and operation and maintenance procedures which should be practiced or avoided in order to minimize discharge of pollutants from offshore facilities.

Produced water is receiving major emphasis in this study as it constitutes the largest single source of waste discharged from offshore facilities. A characterization scheme, which will define the principal constituents of produced water, is being developed in terms of the treatment technology for oil contaminated water. For example, the characterization scheme will define oil particle size distribution and stability for the following oil conditions:

free oil
emulsified oil
dissolved oil
oil wet solids

A pollution control rational for produced water will be used to evaluate equipment designs, operation and maintenance procedures and human engineering factors from the viewpoint of pollutant minimization. The rationale will be confirmed by field and laboratory analysis of samples. For example, the rationale could state that a well head choke contributes significantly to the oil in water emulsion problem and that the substitution of a down hole choke will reduce this problem. The proof of this rationale would then be the sampling and oil particle size analysis performed on platforms using these two control systems.

Another study, being conducted with the U.S. Geological Survey, is developing criteria for use in determining shoreside impact of offshore development. It is well understood that offshore facilities cannot exist without support from onshore bases. What is not well understood is the social, economic, and environmental effects of this onshore expansion. For example, in a recent study sponsored by the American Petroleum Institute,(5) it was estimated that an additional 60,000 people will be required to support the offshore industry in the Mid-Atlantic area only. Additional shoreside facilities occupying 3 to 4 square miles of coastal area will be required as well. In the Gulf of Mexico and Southern California OCS areas the product is brought to shore by pipelines. However in the Atlantic and Gulf of Alaska it is anticipated that development will take place far offshore (beyond 30 miles). Therefore, a question that must be answered is "how will the products from these two frontier areas be brought to shore?" If by tanker, than where should the port facilities be built? If by pipeline, where should the pipeline corridors be located? Under the EPA-USGS study, planning criteria will be developed and then discussed with officials from coastal communities. Through iterant analysis, the criteria will be refined several times prior to final publication. It is felt that this approach will produce a document with wide acceptance throughout the planning community.

According to the Oil Spill Prevention, Control and Countermeasures Plan Review Manual, which was prepared by Rice University and the University of Texas for the Environmental Protection Agency, the most probable source of leaks and spills from oil producing facilities is from pipes, valves and fittings. Regardless of the type of equipment used to store or process oil, the oily material must be moved by pumping it though pipes, valves and fittings. In assessing the oil spill potential in piping systems, the most important factors to be considered are the compatibility of the pipe with the other material being handled, the range of temperatures and pressures involved, and the overall construction integrity of the pipe material. Leak detection and pipeline systems installed above ground or above water consists primarily of onsite inspection. Despite sophisticated electronic flow-monitoring electronic equipment, the most reliable underwater and underground leak detection method is again visual inspection. This inspection is most commonly performed by aircraft. Currently available flow monitoring equipment can detect pipeline leaks in the neighborhood of 0.1 to 1.0 percent of the total throughput.(6) Thus, pipelines can leak a substantial quantity of oil undetected. For example, a 50,000 barrel per day pipeline could lose from 50-500 barrels, or 2,100 to 21,000 gallons of oil a day undetected. This would be classified as a significant pollution incident. A study is currently being prepared that will assess the state-of-the-art for pipeline leak detection and make recommendations for advancing the technology in areas which look promising.

Because of the increased market values of oil, enhanced oil recovery techniques are becoming profitable for onshore production facilities. However, as yet, the environmental consequences of these techniques are not completely understood. Secondary recovery, of which water flooding is the most common, reached a peak about 1965 and has been declining since.(7) This decline is based primarily on economics. However, at present values, tertiary recovery is now being considered. Tertiary recovery generally is considered among the more exotic oil recovery processes and includes miscible displacement, thermal recovery and chemical flooding. These types of enhanced recovery techniques will be applicable to many of the existing onshore oil fields. In order for the U.S. to maintain its oil producing rates, recovery of a "third crop" of oil from those fields which have already undergone secondary recovery is a logical choice. However, there is a sense of urgency in developing new tertiary recovery methods due to the fact that many of those fields in which water floods were initiated in the 1950's have reached the advanced stages of depletion. Some are nearing their economic limit and wells are being plugged and abandoned. Very few prospects are expected to be so profitable that the economics will permit redrilling of wells and replacement of surface equipment. Most tertiary methods are heavy front-end loaded with chemical and/or equipment costs. Anticipating increased development in this area EPA is preparing a study which will assess the environmental impact of enhanced recovery practices. Future work in the area of control technology development for enhanced recovery will depend upon the results of this study.

Oil producing facilities, both onshore and offshore, contribute approximately 26 percent of the spill incidents that occur annually. Most mechanical and sorbent cleanup and control systems have failed when used at sea. Mechanical cleanup devices are limited for the same reasons that containment booms are limited - rough sea state conditions. Generally speaking, booms and skimmers are suitable only for calm water with well defined oil slicks.

Although proponents of particular systems have claimed rough water capabilities, none has proved effective so far and prospects are not promising. Based on studies at EPA's Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT), oil spill recovery operations are limited to currents of less then 0.7 knots with wave conditions in the range 2 ft. in height with a 3 second period.

Sorbents, which have proved more effective than mechanical devices under severe sea state conditions, also are faced with difficulties. For example, recovery efficiencies of a sorbent vary widely for different types of oil. Although straw is cheap and easily obtainable, it becomes waterlogged and does not have high oil retention ability. Further, cleanup efforts with straw have had to rely on hand labor which increases both the cost and the time that the oil soaked straw remains in the water.

Several new sorbent cleanup methods offer some promise of improvement. One system being developed by EPA, broadcasts polyurathane foam over the oil slick and recovers, cleans and reuses it in a totally mechanized process. Other methods use belts or ropes of sorbent material which are drawn through the slick, cleaned on shipboard and returned to the slick in a continuous operation.

The use of dispersants in the U.S. coastal waters is sharply restricted by the National Oil and Hazardous Materials Contingency Plan and state regulations. Primary oil spill response of the United Kingdom and industry operating in the U.K. sector of the North Sea, however, is based on chemical dispersants. Dispersants with toxicity several orders of magnitude less than those used on the Torrey Canyon have been developed by U.K. industries since 1967. The equipment in the North Sea is limited to fire spray units which are capable of spraying dispersants for six hours. The limitations inherent in mechanical containment and cleanup emphasize the need to explore other alternatives, including dispersants.

Oil spills are an eventuality in almost all waterway areas. At the present time oceanfront protection is nonexistent. The current method of operation is to allow the oil to come ashore and then remove it from the sandy or rocky beach using rakes, shovels, and manpower. If the penetration of the oil into the sand is less than two inches and the oil is not fluid, the oil can be raked into windrows of approximately one ft., picked up with shovels and placed into a front end loader or dump truck. If the damage to the beach is more extensive, than mechanical equipment must be used. Through a research project sponsored by EPA, it was determined that a motorized elevating scraper used in tandem with a motorized grader, are the best mechanical equipment to use for beach restoration. Rock shore face cleaning has been limited to high pressure, high temperature, water hosing. This is a very difficult and time consuming operation and its effectiveness leaves much to be desired.

PROGRAM DISCUSSION

Investigations in the field of oil pollution control have been carried out by EPA and its predecessors since 1966. From that year through 1972 the research was concerned exclusively with oil spill cleanup and control. Beginning in 1973 the emphasis began to turn to control technology for oil and gas extraction and handling with primary concern in the offshore area. The current program projection defines some 65 tasks in seven major fuctional areas. Many of these tasks represent continuing efforts in particular areas being funded on an incremental basis. Each of the tasks defined has an established target date. In addition, task milestones have been defined and program interdependents identified. The formulation of future milestones is based on previous accomplishments and preceeds in a well defined fashion. Prior to FY-74 the work on oil pollution control was funded entirely from EPA's base budget. Beginning in FY-75 a switch to energy funds was begun and it is intended that in FY-77 this program will be supported entirely with energy funds. The spills research program receives interagency agreements from the U.S. Coast Guard and U.S. Navy primarily for equipment testing at OHMSETT. Only one interagency agreement exists at the present time in the oil and gas control technology area and that is with the U.S. Geological Survey as metnioned previously.

Task priorities for this program are developed to meet the requirements of the Office of Research and Development. However, because of its "response type" nature this is one of the few research programs able to identify real customers in the operational area. This is particularly true for the spills research program. As a result the needs of these "customers" are continually addressed in developing task priorities.

Approximately 90 percent of the work in oil pollution control technology development is being performed under contract or grant agreements. A small inhouse effort in the area of oil spill source identification forms an intragal part of the overall program. Additionally, work at OHMSETT constitutes the only "real world" testing of oil spill cleanup equipment that is conducted in the U.S.

PROJECTION

It is anticipated that over the next four years work in oil spill control technology will diminish as oil and gas production control technology is increased. It is expected that enhanced recovery techniques for onshore facilities will greatly expand in the very near future. Concurrently, control technology for the exotic chemical systems used in tertiary recovery will also be developed. Waste management practices for use onboard offshore facilities will be developed as the field studies varify our pollution control rationale.

It is felt that by providing the oil and gas extraction and handling industry with the basic technology for effluent limitation and discharge control, BATEA and New Source standards for the near offshore and far offshore subcategories can be met.

CONCLUSIONS

The environmental control technology used in the past by the oil and gas extraction and handling industry is inadequate to handle the problems associated with new sophisticated enhanced recovery practices, operational characteristics of frontier OCS development, and increased impact on the public at large. EPA's research program, as outlined, is designed to assess current operational and treatment technology, apply existing state-of-the-art solutions where possible, and advance the state-of-the-art in treatment control technology where required. In the near future the program will place emphasis on developing new oil/water separation technology, waste minimization and management techniques for offshore facilities, and oil spill prevention methodology. More sophisticated monitoring, alarm, and shutdown systems will be developed to minimize the possibility of undetected pipeline leaks or catostrophic breaks. Systems will be developed to detect pin hole leaks. Acoustical or electronic tracing of the lines will be studyed as possible solutions to this problem. The onshore facility citing criteria will contribute more to rational decisions concerning OCS and coastal uses by improving interaction between state and Federal decision makers prior to commiting OCS and onshore resources to development.

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TABLE I

Pollutants in Produced Water

Louisiana Coastal (a) (2)

Pollutant Parameter	Range mg/l	Average mg/l
Oil and Grease	7 - 1300	202
Cadmium	0.005 - .675	0.068
Cyanide	0.01 - 0.01	0.01
Mercury	---	0.0005
Total Organic Carbon	30 - 1580	413
Total suspended solids	22 - 390	73
Total dissolved solids	32,000 - 202,000	110,000
Chlorides	10,000 - 115,000	61,000
Flow	250 - 200,000 bbls/day	15,000 bbls/day

(a) - results of 1974 EPA survey of 25 discharges

- less than

TABLE II

Pollutants Contained in Produced Water
Coastal California (a) (2)

Pollutant Parameter	Range, mg/l	Pollutant Parameter	Range, mg/l
Arsenic	0.001 - 0.08	Phenolic Compounds	0.35 - 2.10
Cadmium	0.02 - 0.18	BOD	370 - 1,920
Total Chromium	0.02 - 0.04	COD	400 - 3,000
Copper	0.05 - 0.116	Chlorides	17,230 - 21,000
Lead	0.0 - 0.28	TDS	21,700 - 40,000
Mercury	0.0005 - 0.002	Suspended Solids	
Nickel	0.100 - 0.29	Effluent	1 - 60
Silver	0.03	Influent	30 - 75
Zinc	0.05 - 3.2	Oil and Grease	56 - 359
Cyanide	0.0 - 0.004		

(a) Some data reflect treated waters for reinjection.

TABLE III

Volume of Cuttings and Muds in Typical 10,000-Foot Drilling Operation (2)

Interval Feet	Hole Size, inches	Vol. of Cuttings, bbl.	Wt. of Cuttings, pounds	Drilling mud	Vol of Mud components, bbl	Wt. of Mud components pounds
0-1,000	24	562	505,000	sea water & natural mud	variable	
1,000-3500	16	623	545,000	Gelled sea water	700	81,500
2,500,10,000	12	915	790,000	Lime base	950	424,000

TABLE IV

Performance of Various Treatment Systems

Louisiana Coastal (2)

Type of Treatment System	Mean Effluent Oil and Grease mg/l	No. of Units in Data Base
Gas Flotation	27	27
Parallel Plate Coalescers	48	31
Filters		
Loose Media	21	15
Fibrous Media	38	7
Gravity Separation		
Pits	35	31
Tanks	42	48

MINING OF OIL SHALE

Eugene F. Harris
U.S. Environmental Protection Agency
Industrial Environmental Research Laboratory
Cincinnati, Ohio

INTRODUCTION

Oil shale is not, geologically speaking, a shale and it contains virtually no oil. It is a sedimentary rock containing organic matter called kerogen which yields synthetic crude and hydrocarbon gas when heated. The oil shale deposits of Colorado, Utah, and Wyoming lie beneath 25,000 square miles (65,104 square kilometers) of land. About 17,000 square miles (44,271 square kilometers) contain oil shale of potential value for commercial development in the foreseeable future. Roughly 80% of the known higher grade oil shale reserves are located in Colorado, 15% in Utah, and 5% in Wyoming. Public lands, administered by the Department of the Interior, contain 80% of the high-grade oil shale. The U.S. Geological Survey has estimated that the total oil shale reserve of the Green River Formation is more than 600 billion barrels of oil and that 80 billion barrels of this reserve are recoverable by modern mining methods. Extensive deposits of sodium minerals such as dawsonite (a carbonate of sodium and aluminum) and nahcolite (sodium bicarbonate) are associated with the oil shale deposits.

The environmental impacts associated with oil shale development are potentially severe. A large part of the western United States, an area noted for its high quality environment, will be subjected to stresses and changes that must be determined and controlled.

The following is a partial list of potential environmental impacts from oil shale mining of concern to EPA:

1. Disposal of "spent shale" or the rock once the kerogen has been removed--saline material, possibly high sediment yield, establishment and viability of vegetative cover, problems of underground disposal.
2. Water pollution from disposal of saline ground water, pollution from sedimentation caused by land disturbances and leaching of spent shale.
3. Possible water and air quality problems from heavy metals and carcinogenic materials.
4. Land use changes due to mining, wildlife disturbances, and loss of agricultural land.
5. Air quality degradation from fugitive dust, especially particulates from mining, solid materials handling and hauling, and emissions from underground mines.
6. Solid waste disposal of residue and spoils.
7. Increase in erosion from mining, haul roads, etc.
8. Changes in subsurface flow patterns and water quality.

TECHNICAL DISCUSSION

The evaluation of the environmental problems and the development of control technology to deal with the problems is severely handicapped by the fact that the oil shale industry in the United States is a potential industry with no mines currently in operation. Data are available from previous mining operations to some extent and "spent oil shales" are available from several types of processing, i.e., TOSCO, BOM, and Paraho. It is expected that conventional mining methods, area surface and room and pillar underground, will be employed in oil shale operations. In addition to conventional methods, in-situ techniques are being tested to retort the oil shale underground. In-situ techniques have a potential for reducing the surface problems of spoil disposal, surface water pollution, and erosion associated with conventional mining methods. However, some in-situ techniques involve substantial underground mining and could pose a much greater threat to the degradation of subsurface water and air quality.

The lack of current activity has the advantage of allowing time for the collection of a substantial amount of pre-mining or base line data. The collection of these data is enhanced by the Prototype Oil Shale Leasing Program of the Department of the Interior. This program has been formulated to make a limited number of leases of public oil shale lands available for private development under controlled conditions. One of the primary purposes of the prototype program is to gain an understanding of the environmental impacts of oil shale development. The program is responsible for the generation of tremendous volumes of data. EPA's role, as regards to the prototype program, is to make certain that all needed data are obtained to properly evaluate the environmental impacts and ascertain the control technology developments needed. Additionally, sufficient data must be acquired to anticipate the environmental problems due to oil shale mining and to formulate plans to control the anticipated problems.

Surface mining of shale will be similar to the large open pit mines involved in the mining of thick coal seams or as in copper mining depending upon the depth of overburden and thickness of oil shale economically recoverable. Activities will include: surface preparation, blasting, overburden removal, loading, and hauling. Underground mining will involve the use of large loading and hauling equipment. Trucks and front end loaders will be able to operate underground because of the large rooms. The rooms may have a width of 60 feet (18 meters) and a height of from 60 to 80 feet (18 to 24 meters). This will require special ventilation and could require the development of control technology to protect air quality.

PROGRAM DISCUSSION

Investigations of the potential environmental impact of a developing oil shale industry have been carried out by EPA and its predecessors for a number of years. The current program includes three active studies. As indicated above, the studies are intended to establish probable environmental areas of concern and to develop approaches and control technology to minimize adverse environmental impacts.

The studies are being conducted by Colorado State University. Two studies involve vegetation of "spent oil shale". Studies have shown that spent shales from certain processes can be used as a medium for plant growth. A question remains as to whether adequate plant and litter cover to control erosion and minimize percolation can be maintained on spent shales under natural precipitation conditions. The cover will depend, among other factors, on aspect, elevation, slope, and on the chemical characteristics of the spent shale. Physical considerations include particle size and color. Spent shales contain too high a concentration of salt for plant and are deficient in nitrogen and phosphorus. The primary objective of the first study is to investigate surface stability and salt movement in spent shales as compared to these factors in spent shales covered with soil and with established vegetation left under natural precipitation conditions. A secondary objective is to evaluate establishment and growth of a limited number of native plant species on the spent shales. The spent shales included in the study are from processes of the U.S. Bureau of Mines and The Oil Shale Corporation. There are two study sites, one at an altitude of 5,700 feet, the other at 7,200 feet. The former site is on federal land on the U.S. Bureau of Mines, Anvil Points Oil Shale Research Facility, near Rifle, Colorado. The latter site is located on a mesa in the Piceance Basin, near Rio Blanco, Colorado.

Runoff and sediment yields will be measured. Ground cover by live plants and litter will be measured bimonthly during the growing season. Soil moisture, salinity, and temperature will also be recorded.

The second study will be an attempt to duplicate on a very small scale possible disposal schemes for the spent shale from the Paraho retorting process. It is assumed that the spent shale will be compacted to an optimum density for pile stability and to minimize percolation through the pile. Then a skin of soil or uncompacted spent shale covered with soil will be placed over the compacted spent shale. This study will be located on the USBM Anvil Points Facility where the elevation is 5,700 feet and the average annual precipitation is about 12 inches. The plots will be placed over a concrete pad so the quantity and quality of percolating water can be measured. Data collected will be as in the first study. In addition, the percolation samples will be analyzed for Ca, Mg, Na, K, sulfates, Cl, nitrates, hydrocarbons, pH, and EC

The third project will utilize the data obtained in the above studies in additLon to collecting data on a specific study. Because various state and federal institutions and agencies as well as private companies are engaged in the collection of water quality and hydrologic date on oil shale locations there is a need for EPA to identify and obtained current data where available. Literature searches and personal contacts will be used to obtain copies of pertinent published data. A major source of information will be from the Prototype Oil Shale Program. From these documents; data, analyses, and conclusions pertinent to the water quality hydrology will be extracted and reported.

It has been found that a most significant aspect of water quality degradation associated with coal strip-mine spoils composed of Late Cretaceous shales, siltstones and sandstones in the Rocky Mountain region is the dissolution of soluble salts. Koffin, et al. report water quality data that indicates the dissolution of salts from the Green River formation is a most significant source of water contamination in the Piceance Basin as well. Further, work by others indicates that processed shale residues have a very high soluble salt content. Thus, the model being developed for coal mine spoils should be directly applicable to oil shale residues and mine spoils should be applicable to oil shale residues and spoils.

The model will have the ability to predict the quantity and quality of surface and subsurface runoff from the oil shale spoils and residues. The major chemical constituents that will be considered are Ca, Mg, Na, carbonates, Cl, and sulfates. The model will also provide sufficient information about the chemical and moisture conditions in the spoil or residue to be of help in spoil management for effective revegetation.

Verification of the model will be based upon data collected on field sites. Originally, the sites were to be located on the Colony Mine property on Parachute Creek and the study was to utilize TOSCO spent shale. The sites may no longer be available due to the withdrawal of Atlantic Richfield from the project. An alternative may be to use the sites established in the first two studies to verify the model. This is yet to be decided.

INTERAGENCY PARTICIPATION

A number of environmental studies are being conducted by government agencies. The Energy Research and Development Administration is conducting projects focused upon in-situ recovery of oil from oil shale. The states of Colorado and Utah and the U.S. Geological Survey are monitoring air and water quality, especially in areas that may be affected by the mining of oil shale. The U.S. Bureau of Mines is conducting a surface and underground mining analysis. EPA maintains contact with these groups through personal visits and formal meetings in order to minimize duplication and to assist in environmental evaluations.

RESOURCES

Table 1

Resources Expended on Oil Shale Mining

$	FY 75		FY 76	
	No. Projects	$K	No. Projects	$K
	3	208	3	162

SUMMARY

Oil shale deposits in the Upper Colorado River Basin are located in the states of Colorado, Wyoming, and Utah. The large percentage of potential commercial deposits are contained in the Green River formation in the Piceance Basin of Colorado. The Green River formation is an Early Tertiary geologic unit, formed in a depositional basin during Eocene time. Both surface and subsurface flow is to the White River. The White River is a tributary of the Colorado.

The natural quality of both surface and subsurface waters is marginal in much of the area. The principal chemical constituents in the water are calcium, magnesium, sodium, bicarbonate, chloride, and sulfate. The source of these contaminants is the soluble salts contained in the geologic material.

Several processing technologies have been proposed and researched. These include in-situ retorting, The Oil Shale Company (TOSCO) process, the Union Oil Company process, the USBM process, and the Paraho process. They all require mining of the raw shale and disposal of a processed shale residue. Both surface and subsurface mining techniques are under consideration. Extensive underground mining and in-situ retorting will modify the quality and patterns of movement of underground water. This will, in turn, influence the quantity and quality of stream flow in surface streams. The disruption of huge quantities of geologic material will expose fresh surfaces to weathering and contact by surface and subsurface waters. This will increase the salinity of these waters and the exposed surfaces and mining activities are potential sources of fugitive dust. Mine dewatering will also influence the water quality and hydrology of the area.

The Environmental Protection Agency must keep abreast of all available and significant data in order to assure development of needed environmental protection technologies and to be in a position to recommend procedures to minimize the environment impact of the oil shale industry upon a fragile western environment. The activities presented in this report describe the means by which the EPA is meeting this need in regard to the mining of oil shale.

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DISCUSSION FOR ENERGY RESOURCE EXTRACTION

Question: One panel member saw the situation as one where surface mining resulted in environmental damage while underground mining resulted in problems of occupational health. Dr. Liverman in his talk noted that many major problems remain unsolved with underground mining, while many surface mining problems have been solved, especially in the East. Is there really a trade-off between the two types of mining, environmental problems versus occupational health, or are there really more environmental problems with underground mining?

Panel Response: The great developments in surface mining reclamation have occurred because of threats to ban it. The industry turned over backwards to develop remedial technology. Pennsylvania provides a good example of the environmental insult. Whole regions of that State had been destroyed because of underground mining. The total damage to society from underground mining has not really been assessed; it must be done.

There are very few situations in the East where surface mining cannot be conducted with proper reclamation. While it has a cost, it can be done. A satisfactory reclamation techology has not been developed for underground mining. It's a long-range problem that yet may be solvable, but it is going to be very difficult.

Question: Have any studies been made regarding the beneficial use of coal mine waste, and secondly have there been studies regarding how the hydrological function could be maintained in the alluvial valley floors where much of the Western agriculture is concentrated?

Panel Response: The biggest problem associated with the beneficial use of coal mine waste is the control of leachates. The British are using their refuse piles very effectively. This includes use as primary fill where about six feet of other material is placed on top of the coal mine waste. Coal mine waste is also used as fill in West Virginia. There have also been investigations of using waste materials for such things as bricks and fill material. Disposal is also possible by returning the waste to underground locations although this is expensive.

In response to the question on aquifers, a number of problems should be mentioned. These problems are not currently serious in the West because of the small size of present mines. However, if land is disturbed over distances of 10-70 miles in the future, then there could be substantial disruption of aquifers. Drainage can be restored. However, natural aquifers consist of a great many small branches. This probably cannot be restored exactly as it was before mining. That would be a physical impossibility. In these large disruptions, there is insufficient data to respond to the question of restoring the aquifers.

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CHAPTER 9

FUEL PROCESSING

INTRODUCTION

Conversion of fuels to usable forms of energy is accomplished with accompanying production of products having detrimental environmental effects. Processing of fuels prior to conversion is accomplished to render the fuels suitable for the conversion process anticipated and to reduce the resulting detrimental environmental effects.

This chapter is concerned with four fuel processes. The first of these processes, Fluidized-Bed Combustion and Coal Cleaning have primary purposes relating to minimizing environmental damage resulting from conversion. The second two processes, production of synthetic fuels and the processing of oil shale, have both environmental importance and are necessary to modify the form of the fuels at the time of extraction to a form suitable to the conversion means in which the fuel will be consumed.

The Fluidized-Bed coal combustion process involves the combustion of coal within a bed of granular non-combustible material such as limestone or dolomite. The technology offers the potential for energy production with low emissions of environmentally harmful pollutants. It simultaneously offers reduced capital and operating costs with thermal efficiencies equal to or greater than efficiencies achieved with conventional combustion equipment. Alternate processes considered include operation at atmospheric pressure and operation at elevated pressures. Data obtained to date suggests that fluidized-bed combustion may be expected to effectively control emissions of SO_2 and NO_x. While data regarding other emissions is less complete, reduction of other pollutants is also likely. Commercial application is expected to be available in the 1980's.

Coal is primarily organic matter containing a number of elementary constituents including sulfur. In American coals, sulfur content may vary from less than 1% to more than 6% in both organic and inorganic forms. Cleaning can be used to reduce the amount of this and other pollutants prior to combustion. Cleaning may be accomplished with either physical or chemical means. Physical cleaning employs various techniques which often depend on differences in specific gravity or surface properties to effect separation of the coal and impurities. Chemical cleaning relies on treatment of the coal with a reagent. Success of various cleaning processes will vary with the constituents of the coal from region to region and even within a mine. Chemical means, however, are expected to produce the highest rates of impurity removal.

Physical and chemical coal cleaning reduces the emission of pollutants on combustion, but produce coal cleaning wastes which are themselves an environmental problem of considerable magnitude.

As an alternative to the direct combustion of coal, it may first be converted to a synthetic fuel. These fuels include liquefaction and low and high BTU gasification produced in a number of processes either existing or under development. Work in progress covers both the development of the processes and assessment of the environmental effects of the technologies.

A related fuel process is concerned with the vast reserves of oil shale. These deposits in the western United States are estimated to contain over two thousand billion barrels of oil. While closely associated with extraction, processing of the shale is required to produce a useful fuel. This processing will proceed in one of two directions. The shale can be mined and processed by retorting on the surface, or it may be processed underground, *in situ*, with the resulting liquids withdrawn by wells. Because of the magnitude of the required processing and the potential for environmental damage, a corresponding program to develop the associated pollution control technology is requisite. The urgency of the development of this energy source necessitates a rapid response in environmental protection methodology.

Fuel Processing

John K. Burchard
Environmental Protection Agency
Industrial Environmental Research Laboratory
Research Triangle Park, North Carolina

Good afternoon.

Although we are well into the second day of this meeting, I feel that this session--on Fuel Processing--represents the start of a somewhat new subject, because this session and tomorrow morning's--on Flue Gas Cleaning--both concern an area not previously addressed at this meeting--Control Technology.

Both sessions relate to a significant problem facing this Nation of energy users. Since this is the first of the two related sessions, I feel it appropriate to present this problem in as simple terms as possible: We clearly have a sufficient supply of domestic fuel; however, the type of fuel we have in greatest abundance (namely, coal) is simply not clean enough to meet our environmental standards. Simplicity ends as we switch from the problem to the solutions.

Essentially, there are five basic solutions to the problem of air pollution caused by burning fossil fuels:

1. Stop burning fuel altogether. (The consequences of this solution boggle the mind.)
2. Burn only essentially clean fuel. (But we all know that the supply cannot keep up with the demand.)
3. Treat our fuel, making it cleaner, before burning it.
4. Change the way our fuel is burned, minimizing the pollutants emitted.
5. Or clean up the emissions following combustion.

The eight papers of this session deal with the third and fourth of the five solutions I just mentioned: cleaning up our fuel before burning it, and modifying the combustion process itself.

THE AUTHORS

Before examining the papers, I would like to say just a word about their authors, all of whom were selected for their familiarity with the different approaches being taken by Government research and development toward the goal of a viable answer to this Nation's energy needs and environmental concerns.

Three of the authors discuss fluid-bed combustion: Bruce Henschel, of EPA's Industrial Environmental Research Laboratory in North Carolina, discusses EPA's fluid-bed combustion program from the standpoint of environmental characterization.

Al Jonke, from the Argonne National Laboratory, discusses the same subject, but aims his remarks at ERDA's program on process development (This paper is co-authored by Vogel and Swift.)

In the third paper on this subject, TVA's John Reese outlines a comparison study of the cost of two fluid-bed combustion processes (atmospheric and pressurized) with that of flue gas desulfurization.

Three other authors discuss coal cleaning. Jim Kilgroe, again of EPA's Industrial Lab in North Carolina, discusses EPA's interest in physical and chemical coal cleaning, a considerable portion of which has to do with environmental assessment.

Al Deurbrouck, of the Department of Interior, presents a parallel discussion of coal cleaning, outlining, among other aspects, the Bureau of Mines' efforts in control technology development.

The third paper in this area presents another side of coal processing. Eugene Wewerka, of the Los Alamos Scientific Laboratory, discusses work being done for ERDA on discarded refuse from coal cleaning processes. (The co-authors are J. M. Williams and P. L. Wanek.)

EPA's synthetic fuels program is discussed by Bill Rhodes of the Industrial Environmental Research Laboratory in North Carolina, and covers both environmental assessment and control technology development.

The final paper, by Tom Powers of EPA's Industrial Environmental Research Laboratory in Cincinnati, discusses EPA's interest in the relatively little known area of oil shale development.

I will now attempt to briefly summarize the individual papers.

Fluid-Bed Combustion

Three of this session's eight papers relate to research and development in the area of fluid-bed combustion (or FBC): one concentrates on environmental assessment; the second discusses FBC technology development; and the third compares its cost with that of flue gas desulfurization.

FBC Environmental Assessment

Bruce Henschel's paper discusses EPA's program, aimed at the complete environmental characterization of the fluid-bed combustion process. Funded at approximately $4 million per year, the program is being coordinated with ERDA's process development work.

As many of you know, the fluid-bed process involves the combustion of coal within a bed of granular non-combustible material, such as limestone or dolomite. Air is passed up through the distributor plate that supports the bed, causing the granular bed particles to become suspended, or fluidized. This same air also serves in the combustion of the coal; heat generated in the bed can be removed by heat transfer surfaces placed within it. Sulfur removal efficiencies of over 98% have been observed, along with NO_x emissions less than 25% of New Source Performance Standards, in tests on the EPA/Exxon miniplant.

EPA's approach to this program, as it is to the environmental assessment of any energy process, consists of several components. The first step involves identification of the current process and environmental background. This is followed by a comprehensive analysis of pollutant emissions from selected operating units. Next is the development of environmental objectives for the process, considering the emission levels identified in the previous step and their health and welfare effects. Following an assessment of control technology, is an evaluation of the total impact of the process on air, water, and land quality, considering various degrees and costs of control.

In addition, the EPA strategy regarding fluid-bed combustion includes engineering analyses, basic and applied research and development, and specific control technology development. Techniques for lowering the emission of pollutants include: pretreatment of input streams; modification of process design parameters aimed at environmental control; modification of operating conditions; and the possible application of add-on control devices.

Several other Federal agencies are participating in the EPA program. Pass-through funds continue to go to ERDA for EPA's portion of the work being conducted by Argonne National Laboratory. A comprehensive analysis of emissions from the BCURA fluid-bed combustor in England is partially funded by EPA funds to ERDA: ERDA, in turn, is supplementing these funds in a contracted effort with Combustion Systems Ltd.

EPA funds have also been transferred to TVA to support program work relating to solid waste disposal, as well as the cost comparison project to be discussed later. (This cost project, incidentally, is receiving inputs from the Energy Conversion Alternatives Study (ECAS) being carried out by NASA, NSF, and ERDA.) The Federal Energy Administration is also contributing to the effort; its pass-through funds from EPA are supporting work by Exxon on the application of FBC to industrial boilers.

It is inevitable that the complete environmental characterization of fluid-bed combustion (and of other developing energy technologies) will involve a significant effort, considering many potential pollutants that have not received any emphasis in past experimental studies.

FBC Technology Development

Albert Jonke's paper describes Argonne National Laboratory's program, involving investigations of both atmospheric and pressurized fluid-bed combustion concepts. Current stage of the program, underway since 1968, is basic R and D to evaluate fluid-bed combustion at pressures up to 10 atmospheres.

Describing Argonne as "one of several organizations participating in a research and development program designed to develop the concept and to eventually demonstrate at full scale that the FBC process is economical, and meets pollution standards for stationary sources," Jonke describes ERDA's overall program and cites work in this area being sponsored by EPRI and EPA.

An "atmospheric" pilot plant is being built in West Virginia, at Monongahela Power Company's Rivesville Station. With a boiler designed to burn over 10 tons of coal per hour, the project is expected to become operational by mid-1976. Preliminary design is expected to start soon on the next phase: a demonstration plant of at least 200 MW capacity.

ERDA recently accepted a proposal for the construction of a pilot "pressurized" plant. The combustor would be located at Woodridge, NJ and would operate at 7 atm pressure with a 14 MW output. This pilot would lead to conceptual design of a 500 MW commercial plant with a calculated overall thermal efficiency of 41%.

ERDA is also interested in the application of fluid-bed combustion to other than utility power generation, such as coal-burning industrial and commercial boilers and heaters. Several proposals in this area are currently being evaluated.

Reflecting the national fluid-bed combustion program requirements for several 1-5 MWe capacity sub-pilot plant facilities in supporting roles (including the development of unique or advanced concepts), several activities are underway:

1. A pressurized Component Test and Integration Facility (CTIF) has been proposed for construction at Argonne.

2. An atmospheric CTIF is under design at the Morgantown Energy Research Center.

3. An experimental unit is under construction at Oak Ridge National Laboratory to study application of the FBC process to provide total energy requirements (heat and electricity) for small communities.

4. ERDA is partially funding the construction of a pressurized process development unit in England, with sponsorship by the International Energy Agency.

ERDA, along with many utilities, feels that fluid-bed combustion offers cost, efficiency, and reliability advantages over conventional boilers with stack gas scrubbers, by avoiding energy losses required for scrubber operation, the cost of scrubbers, and forced plant outages resulting from scrubber malfunction. However, this issue is still open to question; hence the need for the study described in the following paper.

FBC/FGD Cost Comparison

John Reese's paper compares the cost of fluid-bed combustion with that of flue gas desulfurization.

The aim of the study is the development of conceptual designs, and comparative capital and operating costs, for three systems for reducing pollution:

1. An atmospheric FBC steam power plant.
2. A pressurized FBC combined-cycle power plant.
3. A conventional coal-fired power plant equipped with flue gas desulfurization equipment.

The project is a complex one, indicating the depth in which the study is being conducted and, hopefully, ensuring the validity of the results. This complexity is indicated by the following points:

1. TVA is the performing agency.
2. TVA is utilizing inputs (in the form of fluid-bed combustor designs and capital and operating cost estimates) from the previously mentioned ECAS study.
3. General Electric Company is contractor-in-charge of energy conversion systems and overall plant design for the ECAS inputs to the program.
4. Foster Wheeler Energy Corporation is responsible for furnace designs for the ECAS inputs.
5. Bechtel Corporation is designing the flue gas desulfurization system and the balance of the plant systems.

The conceptual designs are nearing completion, and most major design specifications have been selected for the three cases to be studied. The three will be as nearly equal in characteristics as possible, to ensure that comparisons are valid. Nominal ratings for all cases are about 900 MW, and steam conditions are identical: 3500 psi and 1000°F. Coal is the common fuel: 70%<200 mesh pulverized coal for the conventional unit; and 1/2 inch or less crushed coal for the FBC units.

When completed, the study will be a useful guide for assessing the advantages of fluid-bed combustion, as compared with flue gas desulfurization. Because it will identify major design features that require further development for improved process economics, the study will also help provide a better definition of R and D priorities.

Coal Cleaning

Three other papers in this session relate to coal cleaning. Two of them deal with physical and chemical coal cleaning, but again differ in approach: one concentrates on environmental assessment and pollution control activities; the other stresses process technology development. The third treats an interesting aspect of the same subject: trace pollutants from process refuse.

Physical and Chemical Coal Cleaning (Assessment)

Jim Kilgroe's paper, indicating the need for cleaner burning coal, states that in 1974, nearly 31 million tons of air pollutants--mainly SO_x, NO_x, and particulates--were emitted as the result of coal combustion.

EPA-supported programs have established the technical feasibility of both physical and chemical coal cleaning. These same programs have also identified the degree to which the two forms of cleaning can be used for desulfurization. They indicate that, although these types of cleaning are, in some cases, less costly than other SO_2 emission control strategies, their range of application is not [illegible] broad, due to the inherent properties of some coals.

The cleanability of coal, particularly for sulfur, is dependent upon the form of contaminant. Sulfur in coal exists in two forms: organic sulfur, bonded to the coal structure; and inorganic (or pyritic) sulfur, generally in the form of iron pyrite. U. S. coals vary widely in the relative amounts of each type. Physical coal cleaning, with equipment normally used for the removal of ash and mining residues, is capable of separating coal and pyritic sulfur; some types of chemical cleaning are capable of removing both pyritic and organic sulfur.

Physical coal cleaning involves the use of many physical separation techniques, singly or in combination. They depend on the differences between the physical properties of the coal and the impurities, to achieve separation. Techniques now widely used on a commercial basis include: jigging, heavy media separation, tabling, and flotation. Among other techniques evaluated by EPA, the Bureau of Mines, and Bituminous Coal Research, Inc. since 1965 are: thermal-magnetic separation, immiscible liquid separation, selective flocculation, electrokinetic separation, and froth flotation. Techniques that rely upon specific gravity differences between the coal and pyritic particles, have been found to be the most commercially viable for desulfurization.

Chemical cleaning of coal, to selectively remove undesirable constituents while maintaining the structural integrity of the coal matrix, is an approach to pollution control that is currently receiving increased emphasis. Unlike physical coal cleaning, chemical coal cleaning is not now used commercially in coal preparation processes; however, if successfully developed, it possesses the potential for removing both organic and pyritic sulfur from coal.

In chemical coal desulfurization, finely ground coal is treated with a reagent under specified pressure and temperature conditions. The amount of pyritic and organic sulfur removed from the coal structure depends on the coal particle size, the coal physical and chemical properties, the reagent, the pressure and temperature, and the duration of the reaction.

Additional bench and pilot scale work is required to define the appropriate combinations of parameters for optimum chemical removal of sulfur. Once these variables are established for each process, the next step would be continuous pilot and demonstration scale process studies.

The relatively low costs of physical and chemical coal cleaning processes should make these pollution abatement techniques increasingly attractive in future years. Coals which are amenable to physical cleaning for pyritic sulfur removal will be identified and used in preference to other coal sources. In some instances, a combination of physical coal cleaning and flue gas desulfurization will be used as the most economical method of sulfur emission control. Although physical coal preparation is now widely used for ash and mining waste removal, the use of this technology for substantial sulfur removal will probably not occur until after 1985. The major development focus for physical coal cleaning will be in:

1. Improved techniques for separating fine coal and pyrite.

2. Improved process control to ensure that the product meets sulfur, ash, and Btu specifications.

3. Improved techniques for dewatering and handling coal fines.

4. Improved pollution control in waste disposal methods.

Chemical coal cleaning has a wider area of application than its physical counterpart, since a greater fraction of the total sulfur can be removed. Cost estimates indicate that chemical cleaning should be competitive with flue gas desulfurization and synthetic fuel from conversion processes. However, additional development is needed before this method of sulfur emission control is used widely.

Physical and Chemical Coal Cleaning (Process Development)

Al Deurbrouck's paper, describing the Bureau of Mines' interest in physical and chemical coal cleaning, regards coal preparation as a proven technology for upgrading raw coal by physical removal of associated impurities.

Indicating that the impurity of principal concern is sulfur, in both pyritic and organic form, Deurbrouck says that, generally speaking, organic sulfur cannot be removed by physical means. However, researchers have made some progress in removing organic sulfur without changing the physical characteristics of the coal. Commercially, physical desulfurization of coal is limited exclusively to pyritic sulfur.

Washability examinations of more than 400 U. S. coals show significant pyritic sulfur reduction potential when coals are crushed to liberate impurities, and then subjected to specific gravity separations. A pyrite flotation process is discussed, showing potential for maximizing the removal of pyritic sulfur.

The Bureau of Mines also has some interesting studies underway aimed at the removal of impurity water from coal; of particular interest is its application to the upgrading of lignite.

Lignite coal deposits in Montana and North Dakota represent one of the largest relatively untapped fossil fuel reserves in the U. S., totalling more than 220 billion tons of recoverable low-sulfur-content fuel. However, lignite utilization has been limited because of the material's high moisture content (approximately 40%), as well as its tendency to combust spontaneously and its often high sodium content. The Bureau of Mines is now working to produce a lignite pellet containing less than 10% moisture at a low sodium content.

For coal preparation to be a totally viable process (i.e., for it to be applicable to the removal of both organic and pyritic sulfur from coal), chemical desulfurization must be developed further.

Several such methods have been investigated at the Pittsburgh Energy Research Center.

The one showing the most promise at this time requires only the simplest of reagents, air, and water. Tests have shown that heating coal with compressed air (400-1,000 psi) and water to 150-200°C, at residence times up to 1 hour, converts all the pyritic sulfur (as well as up to 45% of the organic sulfur) to aqueous sulfate (most of it appearing as sulfuric acid). Use of such a process would help make a large portion of Eastern and Midwestern coal environmentally acceptable as boiler fuel.

Deurbrouck's paper concludes on a heartening note. He states, "Coal preparation, an old friend, could well become one of the glamorous new technologies to emerge as a result of the energy crisis."

Process Refuse Pollutants

Eugene Wewerka's paper goes a step beyond the work described by the first two papers on coal processing. The work he describes relates to the environmental problems generated by the refuse that is discarded from coal cleaning operations.

At the root of the problem is the fact that as-mined coal contains a great deal of extraneous rock and mineral matter (the inorganic constituents often represent as much as 30-40% of run-of-the-mine products). Because these impurities not only produce pollutants but also are expensive to ship and dilute the heating value of the coal, nearly half of all the coal mined in the U. S. is processed to remove the unwanted material.

This unwanted material from coal preparation facilities, and other coal mine refuse--comprises the gob piles or culm banks that are scattered over thousands of acres in the coal-producing areas of the U. S. An estimated 2 billion tons of carbonaceous mineral wastes have been accumulated in the U. S. from coal preparation and mine development. Another 100 millions tons are added each year.

In addition to all the known problems caused by the accumulation of this waste material, our attention has turned recently to the environmental hazards posed by the vast array of potentially harmful trace elements in coal refuse materials. Many of the mineral components of coal wastes are released into the environment by oxidation and aqueous leaching during natural weathering; it is likely that additional mineral matter is volatilized by burning wastes. Compounding this particular problem is our ignorance concerning the fate of trace elements during weathering and waste burning.

So little is known in this area, in fact, that the EPA/ERDA program at Los Alamos Scientific Laboratory has had to start with fundamentals.

The program involves the assessment and definition of the magnitude of environmental problems resulting from trace elements in coal processing wastes, and the development of appropriate pollution control measures. The focus of the program's initial stages is on obtaining basic information about the structure and behavior of these materials.

Once this fundamental information is acquired, the program will progress as follows:

1. Laboratory and field investigations to determine the fate of trace elements during weathering and burning of coal wastes, and to identify those of possible environmental concern.
2. Development of chemical or physical methods for controlling environmental contamination from these waste materials.
3. Investigation of methods for economically removing useful trace constituents from coal refuse.

Synthetic Fuels

Bill Rhodes' paper sees EPA's synthetic fuels program as part of a 2-year-old commitment--documented in the Dixie Lee Ray energy report--to utilize more fully the natural resources of the U. S., and to become less dependent on foreign sources of energy. He points out that, along with our energy commitment, we have an equally significant commitment to adequately protect our environment.

Actually, EPA's interest in this work area predates the Ray energy report. This interest is reflected in the progress of various programs already underway to determine the environmental factors in the production and utilization of synthetic fuels from coal. The program is divided into two basic parts: environmental assessment and control technology development.

The overall objective of the assessment portion of the program is to ensure an environmentally sound synthetic fuels industry. To that end, past and current efforts utilize existing information to perform multimedia environmental source assessments. Actual and proposed Federal, State, and local standards and guidelines are reviewed to establish baselines for the assessments. As information gaps and needs are identified, projects are initiated to acquire the data needed. Data acquisition is all-important. This requires knowledge of existing data, cooperation of plant operators, identification of sampling and analytical techniques, test program development, and an overall data analysis scheme.

The basic objective of the control technology portion of the program is to ensure that the required environmental controls are available in a timely and cost-effective manner for the synthetic fuels area. This work includes: identification of environmental control technology alternatives, evaluation of the applicability of existing control methods to known and potential problems, design and cost studies, field tests to determine the acceptability of existing control methods, and the evaluation, development, and demonstration of new or novel methods.

EPA's synthetic fuels program includes environmental assessment of low- and high-Btu gasification and coal liquefaction, improved control methods for fuel converter streams, products and by-products, fuel storage, preparation, and feeding and system wastes. Specific control activity areas include hydrodesulfurization, hydrodenitrification, dolomite cleanup, acid gas cleanup, gas, liquid, and solid waste treatment, disposal techniques, and fugitive emissions.

The synthetic fuels paper cautions that it is imperative that the environmental detriments of our coal-to-synthetic-fuels program be thoroughly and carefully analyzed, and the alternatives weighed. Inadequate and piecemeal environmental data was used as the basis for initial work, because there was no alternative. With the cooperation of industry, universities, and government agencies, better data will be produced which will result in an important, credible contribution to bettering the quality of life.

Oil Shale Processing

Tom Powers' paper on oil shale processing is significant in that it relates to a truly vast source of potentially available energy in the U. S. This significance is borne out by the following statistics:

1. High quality shale (>25 gallons of oil/ton of shale), mostly in Colorado, Utah, and Wyoming, contains an estimated 2.2 trillion barrels of oil.
2. Lower quality shale (10-25 gallons/ton), located throughout the U. S., could produce an additional 40 trillion barrels of oil.

However, getting the oil out of the shale is not simple. As this resource is developed, it will be necessary to protect the environment by applying adequate control strategies for the mining and processing of the shale. Because of the magnitude of these processing activities and their potential for environmental damage, EPA has undertaken a program that will lead to the identification, development, and demonstration of cost-effective pollution control technology.

EPA's overall strategy relates to six major activities: exploration, mining, shale preparation, processing, land reclamation, and product transportation. Efforts for controlling emissions, effluents, and solid waste residues include environmental impact analyses, pollutant characterization, evaluation of available control technology, and development of new control techniques.

Although pollution abatement programs for coal mining have existed for many years, oil shale mining will require different environmental controls. Petroleum refinery controls have also existed for many years; however, the needs for oil shale refineries are unknown at present. Oil shale retorting is a relatively new process; it may involve by-product recoveries of metals as well as of hydrocarbons.

In comparison to the closing of an earlier paper, Powers' closing is a bit more conservative. He first says, "The potential for oil shale development in the United States appears great." But then, adds realistically: "The potential for environmental impact from oil shale development is also great."

I would like to be able to conclude my summary of these papers by giving you a clear picture of the total monetary efforts being expended in the areas under discussion. Unfortunately, I can't quite manage this because of budget complexities, and the unavailability of estimates of resource allocation by private industry.

However, I can outline what is being spent by EPA, and by other Government Agencies utilizing our "pass-through" funds.

I am speaking of a program that represents about $13.5 million in FY 76. (Of this amount, about 18% is in the form of pass-through funds.) About one-third of the program is for environmental assessment, and about two-thirds for pollution control technology development. Our current annual funding is running about:

$4.4 million for fluid-bed combustion;
$3.8 million for physical and chemical coal cleaning;
$2.8 million for synthetic fuels; and
$2.3 million for advanced oil processing.

I am confident, that with the on-going effort in these and other programs, we will attain both the energy and environmental goals of our Nation.

THE U. S. ENVIRONMENTAL PROTECTION AGENCY PROGRAM FOR ENVIRONMENTAL CHARACTERIZATION OF FLUIDIZED-BED COMBUSTION SYSTEMS

D. B. Henschel
Industrial Environmental Research Laboratory
Office of Energy, Minerals and Industry
Office of Research and Development
U. S. Environmental Protection Agency
Research Triangle Park, North Carolina 27711

Awareness of environmental considerations is increasing, including attention to an expanded number of potential pollutants of possible concern from energy generation processes. Thus the need is intensified for comprehensive environmental characterization of existing and developing energy technologies.

One promising new energy technology that is being developed is fluidized-bed combustion of coal for heat, steam and power generation. This technology offers the potential for energy production with low emissions of environmentally harmful pollutants, and simultaneously with reduced capital and operating costs and with thermal efficiencies equal to, or greater than, the efficiencies achievable with conventional combustion equipment. The U. S. Energy Research and Development Administration (ERDA) is conducting a substantial program to develop fluidized-bed coal combustion technology. The ERDA program currently includes: a number of support projects; a 30 MW coal-fired fluidized-bed boiler under construction at Rivesville, West Virginia, to be operated with the bed at essentially atmospheric pressure; a 13 MW elevated pressure fluidized-bed combustion combined cycle system to be built in Wood Ridge, New Jersey; and a variety of other facilities which are envisioned to demonstrate coal-burning fluidized-bed combustion technology in alternative applications and at alternative scales of operation.

In coordination with the ERDA development program, the U. S. Environmental Protection Agency (EPA) is conducting a contract research and development program, valued at about $4 million in fiscal year 1976, aimed at complete environmental characterization of the fluidized-bed coal combustion process. As part of the EPA program, interagency transfers of funds have been effected to obtain the assistance of ERDA, of the Tennessee Valley Authority and of the Federal Energy Administration in carrying out the environmental characterization.

Since the combustion technology development activities and the environmental characterization effort are being conducted in parallel, there is increased potential for improved environmental control and reduced control costs for fluidized-bed combustion systems resulting from effective consideration of environmental aspects during the technology development.

BACKGROUND

The fluidized-bed coal combustion process involves the combustion of coal within a bed of granular, non-combustible material, such as limestone or dolomite. The bed is supported by a distributor plate. Air is passed up through the distributor plate, causing the granular bed particles to become suspended, or fluidized. This air also serves as the combustion air for the coal. Heat generated in the bed can be removed by heat transfer surface placed in the bed.

A number of variations of the process are being considered, differentiated according to process variables such as operating pressure in the bed and the presence or absence of heat transfer surface in the bed. The alternative variations of the fluidized bed coal combustion process may find application in electric utility power generation, in industrial steam and power production, and perhaps in residential/commercial heating. The fluidized bed coal combustion process is expected to achieve commercial application in the 1980's.

Utilization of a sulfur dioxide (SO_2) sorbent such as limestone or dolomite as the bed material has been found to be effective for control of SO_2 emissions from coal-fired fluidized bed combustors. Sulfur removal efficiencies of 90 to 95 percent, or even higher, have been characteristically observed on experimental units employing limestone or dolomite sorbent on a once-through basis. In atmospheric-pressure systems, removals of 90 percent and above are typically achieved with once-through addition of fresh limestone or dolomite at sorbent feed rates such that the moles of calcium in the sorbent feed are 2 to 4 times the moles of sulfur in the coal feed. Some data have indicated that high removals might be obtainable with even lower calcium-to-sulfur mole ratios if small quantities of sodium chloride are also fed to the system. In elevated-pressure systems, SO_2 removals of 90 percent and above are typically obtained with once-through addition of dolomite at calcium-to-sulfur mole ratios of 1.5 to 2; with limestone as the sorbent, calcium-to-sulfur mole ratios of 1.5 to 2 generally provide SO_2 removals of about 70 percent. Limited laboratory-scale data indicate that suitable pretreatment of dolomite prior to utilization, such as precalcination, may enable even lower calcium-to-sulfur mole ratios.

Testing for nitrogen oxides (NO_x) on a variety of experimental equipment has indicated that atmospheric pressure fluidized-bed combustors, operating at about 20 percent excess air, generally contain around 250 to 450 ppm NO_x (about 0.3 - 0.6 lb/10^6 Btu, or 0.13 - 0.26 g/10^6 J, expressed as NO_2) in the flue gas, compared to the EPA New Source Performance Standard of 0.7 lb/10^6 Btu (0.30 g/10^6 J) for coal-fired boilers. Some data indicate that emissions of only 200 ppm (0.25 lb/10^6 Btu, or 0.11 g/10^6 J) or below may be achievable on atmospheric-pressure systems. Elevated-pressure experimental systems with heat transfer surface in the bed, operating at about 20 percent excess air, typically emit between 100 and 250 ppm NO_x (0.12 - 0.3 lb/10^6 Btu, or 0.05 - 0.13 g/10^6 J, expressed as NO_2). Limited data on elevated-pressure systems without heat transfer surface in the bed, operating at high excess air levels, indicate NO_x emissions (in terms of lb/10^6 Btu or g/10^6 J) higher than those given above for pressurized systems with heat transfer surface in the bed; NO_x data from systems without transfer are currently limited, so that a widely-applicable range of emission levels cannot be stated at the present time for these systems.

Thus the significant quantity of data which have been developed to date regarding SO_2 and NO_x emissions suggest that fluidized-bed coal combustion may be expected to effectively control emissions of these pollutants. Data on emissions of many other pollutants from fluidized-bed combustors are less complete. The EPA fluidized-bed combustion program is intended to develop an improved understanding regarding the emissions and control both of those pollutants which have received emphasis in past fluidized-bed combustion studies, and of those for which little data are currently available.

GOAL OF THE EPA PROGRAM

The goal of the EPA fluidized-bed combustion program is to obtain all necessary environmental data over the full range of variables for all variations of the fluidized-bed combustion process. It is desired to obtain these data on a suitable experimental scale, and on a time schedule compatible with the development schedule envisioned in the national fluidized-bed combustion development effort.

The necessary environmental data include adequate data regarding all media (air, water, land) to enable determination of the total environmental impact of the process. It must be assured that the process will meet current and anticipated future environmental standards. Furthermore, if future health effects studies or related work identify the need for additional standards not formally anticipated at this time, sufficient data regarding the fluidized-bed combustion process must be available to allow recommendations to be made regarding such standards proposed in the future. Also, it is desired to develop adequate data to enable determination of means to minimize the process environmental impact by means of suitable control technology.

The full range of operating and design variables is being considered to identify whether there are any ranges of particular variables which are especially favorable or unfavorable from the environmental standpoint.

The variations of the fluidized-bed combustion process that are being considered include, for example: combustor operation at elevated pressure versus operation at essentially atmospheric pressure; operation of the combustor with steam or air-cooled tubes immersed in the bed versus "adiabatic" operation with no immersed cooling surface; and regeneration of the sorbent for sulfur oxides control versus non-regeneration.

It is necessary to obtain the environmental data on an experimental scale such that the data can reliably be scaled up to commercial-scale systems, and such that the environmental impact of the process can be identified for full-scale units.

The environmental data must be generated on a time schedule compatible with the national program to develop fluidized-bed combustion, so that any potential environmental problems can be identified and addressed, and so that any necessary control technology can be developed, by the time that the process is ready for commercial application.

STRATEGY OF THE EPA PROGRAM

In order to achieve the goal indicated above, the EPA fluidized-bed combustion program is divided into two major sub-objectives: environmental assessment and control technology development. See Table 1.

Environmental Assessment

In general, environmental assessment of an energy process is sub-divided into a number of components (Reference 1), as indicated in Table 1.

The first step in environmental assessment involves identification of the current process and environmental background. This effort would include, for example: study of process flowsheets; identification based on flowsheets of locations within the process where emissions may occur; application of theoretical calculations and engineering considerations to project, prior to actual emission measurements, what the emissions may be of all potential pollutants, including those for which data may not be available; and collection of health and property effects data for potential pollutants.

The next step in environmental assessment is comprehensive analysis of emissions from selected operating units. Comprehensive analysis would involve measurements for all pollutants in all media, to identify what pollutants are actually being emitted from what locations within the process. Ambient monitoring around the process site might also be included. A key point to be made regarding comprehensive analysis is that it would include not just the pollutants that have been emphasized in the past (such as SO_2 and NO), but would address all possible pollutants. For example, comprehensive analysis would address: SO_2; SO_3; sulfides, sulfites and sulfates; reduced sulfur species in the flue gas, such as H_2S, COS and CS_2; NO; NO_2; nitrites and nitrates; reduced nitrogen compounds in the flue gas, such as NH_3 and cyanides; individual organic compounds, including, for example, specific polycyclic organic compounds; halogens; all trace elements and trace element compounds that might be expected based upon the composition of the coal ash and the sorbent; particulates, including total mass, size distribution and morphology; and biological testing of selected samples, including cytotoxicity, mutagenicity, and, if necessary, carcinogenicity. A complete comprehensive analysis would probably be conducted on any one operating fluidized-bed combustor at a relatively small number of sets of operating conditions.

A third step in environmental assessment is development of environmental objectives for the process, considering the pollutant emission levels identified in the comprehensive analyses, and considering the health and property effects of the pollutants. Pollutants would be prioritized, and emission goals set. Four levels of control that might be considered are: (1) control based upon existing technology; (2) control based upon existing Federal and state standards; (3) control based upon projected health and property effects; and (4) "zero discharge."

Environmental assessment also includes assessment of control technology. This effort would include, for example: identification of possible control technology for achieving the emission goals set in the preceding step; evaluation of the cost of alternative degrees of control; and assessment of the environmental impact of the control process itself.

Based upon the information obtained during the previous steps of the environmental assessment, an evaluation would be made of the total impact of the process on air, water and land quality, and on human health and on property, considering various degrees (and hence costs) of control.

The final step of environmental assessment, indicated in Table 1, is the development of a program for obtaining the additional environmental information that is found to be necessary during the other steps. Such additional information might include, for example: further comprehensive analyses on different units or at different sets of conditions; development or improvement of sampling and analytical techniques for use in comprehensive analysis; additional control device studies; and further basic studies regarding pollutant formation in a fluidized-bed combustor.

Thus environmental assessment can be an iterative process, in which the results of the various steps are updated as additional information regarding the process becomes available.

Control Technology Development

The second major sub-objective in the EPA strategy is control technology development. This activity includes engineering analysis, basic and applied research and development, and specific control process development as required. Environmental control techniques that are being considered for fluidized-bed combustion applications include: (1) pretreatment of the input streams, such as precalcination of the sorbent; (2) modification of process design conditions for the purpose of environmental control; (3) modification of operating conditions; and (4) application of add-on control devices.

THE EPA PROGRAM

The EPA fluidized-bed combustion program to carry out the above strategy is, as indicated previously, predominantly a contract and interagency agreement program which is funded in fiscal year 1976 at a level of about $4 million. The program currently consists of fifteen projects with a variety of contractors.

For the purposes of this discussion, the fifteen projects have been arranged into five categories, and are listed in Table 2. A simplified milestone chart is shown in Figure 1.

These projects are briefly described below.

Broad Environmental Assessment

The primary environmental assessment contractor--the first contractor listed under "Broad Environmental Assessment" in Table 2--will have primary responsibility for carrying out all of the environmental assessment tasks indicated in Table 1. This effort will involve a three-year, 60,000 man-hour contract.

Prior to the award of the main environmental assesssment contract, GCA/Technology Division is conducting a preliminary environmental assessment effort. A key task in the GCA study is the utilization of theoretical calculations and of engineering evaluation to project *a priori* what the emissions may be from fluidized-bed combustors of potential pollutants which have received little, if any, attention in past experimental studies. This task is thus a part of the first environmental assessment step indicated in Table 1; i.e., identification of current background. As part of this effort, GCA is also briefly assessing possible control technology for use on pollutants projected to be emitted in significant quantities. The GCA effort was completed in January 1976, and the final report is in preparation.

Comprehensive Analysis of Emissions

Four comprehensive analysis projects are in advanced stages of planning or preparation. Battelle Columbus Laboratories is developing an approach for comprehensive analysis on fluidized-bed combustion units, and is to test the approach by conducting an analysis using a 6-inch (15 cm) i.d. atmospheric-pressure fluidized-bed coal combustor. A comprehensive analysis is also planned on the 2-foot by 3-foot, or 61 cm by 91 cm (cross-section) pressurized combustor at the British Coal Utilization Research Association, while this unit is being operated under ERDA sponsorship. Also a comprehensive analysis is scheduled on EPA's 7-foot (210 cm) i.d. pressurized adiabatic CPU-400 pilot plant at Combustion Power Company, while the plant is burning coal under ERDA sponsorship. Aerotherm/Acurex Corporation and TRW, Inc., are participating in the sampling and analytical activities, respectively, on this effort. Finally, comprehensive analyses are to be conducted on the pressurized bench-scale fluidized-bed combustion equipment and the pressurized Miniplant system at Exxon Research and Engineering Company while these facilities are being operated under EPA sponsorship. The units at Battelle, BCURA, Combustion Power and Exxon represent the spectrum of variations of the fluidized-bed combustion process.

It is anticipated that comprehensive analyses will also be conducted on a variety of other fluidized bed combustion units as plans develop and as these other units become available.

As part of the comprehensive analysis effort, The Mitre Corporation is preparing manuals for each of the fluidized-bed combustion process variations, indicating alternative sampling and analytical procedures that can be employed for the various potential pollutants for each variation, tentatively recommending preferred procedures and identifying sampling/analytical technique research and development requirements. The Mitre study should be completed in April 1976.

As indicated by the last entry under "Comprehensive Analysis of Emissions" in Table 2, an extensive continuing effort is underway by EPA with a variety of contractors to develop new and improved sampling and analytical techniques. This effort is not part of the fluidized-bed combustion program *per se*, but is in support of all of EPA's activities.

Solid and Liquid Waste Disposal

Two projects are planned which will address specifically the question of solid and liquid waste disposal from fluidized-bed combustion systems. The primary contract for assessment of solid and liquid waste disposal and utilization (the first contract listed under "Solid and Liquid Waste Disposal" in Table 2) has recently been awarded to Ralph Stone and Co. In addition, the Tennessee Valley Authority (TVA), under an interagency agreement with EPA, is studying solid waste processing.

In general, these studies involve: (1) characterization of solid and liquid waste materials from variations of the fluidized-bed combustion process; (2) laboratory and field studies to identify, e.g., solid leaching properties and the effect of long-term exposure of solid by-products to the environment; (3) laboratory studies of physical/chemical treatment of solid wastes to reduce the environmental impact upon disposal; and (4) laboratory and marketing studies of the potential for manufacturing marketable products from solid wastes.

Other contractors may become involved in solid waste disposal/utilization studies to the extent warranted.

Experimental and Engineering Studies

A number of experimental and engineering studies are underway which involve tasks in both the environmental assessment and the control technology development sub-objective areas.

Westinghouse Research Laboratories is conducting engineering and primarily laboratory-scale experimental studies. Argonne National Laboratory, in a project co-funded with ERDA, is carrying out laboratory and bench-scale work, including testing on their 6-inch (15 cm) i.d. pressurized fluidized-bed combustor and the 4-inch (10 cm) i.d. pressurized sorbent regenerator. Exxon Research and Engineering Company is conducting a program on their bench-scale fluidized-bed combustion/sorbent regeneration equipment, and on the Miniplant system, which includes a 12.5-inch (32 cm) pressurized fluidized-bed combustor capable of burning up to 480 pounds (218 kg) of coal per hour, and an 8-inch (22 cm) pressurized sorbent regeneration vessel. The Westinghouse, Argonne and Exxon projects vary according to their experimental scales and to the details of their individual work plans, but there are several general objectives which are, for the most part, common to each. These general objectives are: (1) investigation of SO_x control from fluidized-bed units using limestone/dolomite sorbents, including regeneration of the sorbents; (2) investigation of SO_x control using alternative sorbents, including sorbent regeneration; (3) study of NO_x formation and control; (4) characterization of particulates emissions, and testing of particulates control devices; (5) investigation of the emissions and control of other specific pollutants, such as trace materials and hydrocarbons; and (6) minimization of other environmental impacts.

A small, flexible, atmospheric-pressure fluidized-bed combustor, referred to as a sampling and analytical test rig, is planned for in-house studies at the EPA site in the Research Triangle Park. This unit would be utilized to address specific environmental concerns without disrupting the on-going test programs on the other more sophisticated units being operated by the various contractors. Subjects to be studied on the rig include: (1) comprehensive analysis of emissions; (2) testing of alternative sampling and analytical techniques; and (3) investigation of alternative add-on control devices.

Paper Studies

Several specific paper studies are underway which, like the experimental projects discussed above, involve effort toward both the environmental assessment and the control technology development sub-objectives.

Dow Chemical is conducting a study to project the effect of experimental scale on emissions from fluidized-bed combustion systems. Fundamental and applied knowledge in the areas of combustion, fluidization and chemical kinetics and thermodynamics is to be employed to estimate the effect of scale on emissions of all potential pollutants, including those for which experimental data may not be available. The results of this project would be used as an indication of the scale on which environmental data may have to be obtained in order to enable reliable scale-up to commercial-scale systems. The Dow study is expected to be completed in March 1976.

Exxon Research and Engineering Company is carrying out an energy, economic and environmental assessment regarding application of coal-fired fluidized-bed boilers in the industrial sector. This study will result in projections of: the applicability of coal-fired fluidized-bed combustion to industrial boilers; the technical requirements of envisioned industrial fluidized-bed coal boilers; the industrial demand for such boilers; the impact on the national energy situation of application of these boilers; the economic impact of the boilers on the industries employing them and on associated industries supplying the user industries; and the environmental impact of industrial coal-fired fluidized-bed boiler application. This project, which is scheduled for completion in March 1976, is co-funded with the Federal Energy Administration and with ERDA.

The Tennessee Valley Authority is conducting a project to develop conceptual designs and comparative capital and operating costs for an atmospheric-pressure fluidized-bed steam power plant, a pressurized fluidized-bed combined cycle power plant, and a conventional coal-fired steam power plant with flue gas desulfurization. This effort is being carried out in coordination with the Energy Conversion Alternatives Study (ECAS) that is underway by the National Aeronautics and Space Administration, the National Science Foundation and ERDA. The TVA project is scheduled to be completed in October 1976.

INTERAGENCY PARTICIPATION

As indicated in the preceding discussion, several other Federal agencies are participating in the EPA fluidized-bed combustion program. Funds are continuing to be transferred to ERDA for the EPA-sponsored portion of the on-going work being conducted by Argonne National Laboratory. The comprehensive analysis of emissions from the BCURA fluidized-bed combustion unit is being partially funded by means of an interagency transfer of funds to ERDA, for inclusion in ERDA's contract with Combustion Systems, Ltd., covering the ERDA-sponsored testing on the BCURA unit. It is anticipated that further funds may be transferred to ERDA for future environmental testing on other fluidized-bed units being operated by ERDA. Funds have been transferred to the Tennessee Valley Authority to support the fluidized-bed combustion solid waste investigation and the fluidized-bed combustion/flue gas desulfurization cost comparison being conducted by TVA. As indicated previously, the TVA fluidized-bed combustion/flue gas desulfurization cost comparison is receiving input from the Energy Conversion Alternatives Study that is being carried out by the National Aeronautics and Space Administration, the National Science Foundation and ERDA. The EPA contribution to the joint FEA/ERDA/EPA study at Exxon Research and Engineering Company, regarding the application of fluidized-bed technology to industrial boilers, is being funded by means of an interagency transfer to the Federal Energy Administration.

CONCLUSIONS

Complete environmental characterization of the fluidized-bed coal combustion process (and of other developing energy technologies) will involve a significant environmental assessment and control technology development effort. This effort will include consideration of many potential pollutants that have not received emphasis in past experimental studies. In coordination with the effort being conducted by ERDA to develop fluidized-bed coal combustion technology, EPA is carrying out a program to provide a complete environmental characterization of the process. As part of the EPA program, funds have been transferred to other Federal agencies in order to obtain their assistance in carrying out this environmental characterization.

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Figure 1. - The EPA Fluidized-Bed Combustion Program

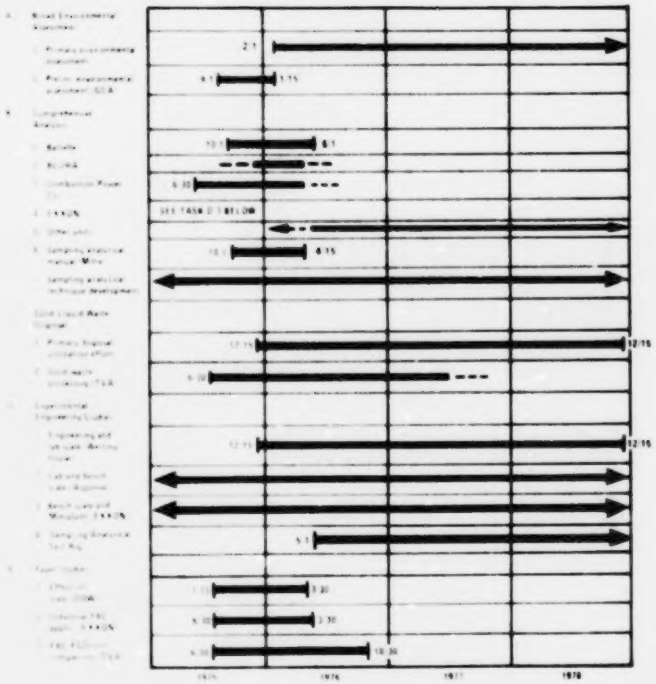

Table 1. - Strategy of the EPA Fluidized-Bed Combustion Program

A. Environmental Assessment (EA)

1. Current process/environmental background
2. Comprehensive analysis of emissions
3. Development of environmental objectives
4. Control technology assessment
5. Environmental impact analysis
6. Development of environmental program

B. Control Technology Development (CTD)

1. Engineering analysis, basic and applied R&D, and control process development for:
   - input stream pretreatment
   - design condition modification
   - operating condition modification
   - add-on devices

Table 2. - The EPA Fluidized-Bed Combustion Program

A. Broad Environmental Assessment

1. **Environmental Assessment/Systems Analysis and Program Support for Fluidized-Bed Combustion (Contractor to be selected)**
2. Preliminary Environmental Assessment of the Fluidized-Bed Combustion Process (GCA Corporation)

B. Comprehensive Analysis of Emissions

1. Comprehensive Analysis of Emissions from an Atmospheric-Pressure Fluidized-Bed Combustion Unit (Battelle Columbus Laboratories)
2. Comprehensive Analysis of Emissions from the BCURA Pressurized Fluidized-Bed Combustion Unit (Combustion Systems, Ltd./BCURA)
3. Comprehensive Analysis from the CPU-400 Pressurized FBC Process Development Unit Burning Coal (Combustion Power Co./Aerotherm-Acurex Corp./TRW, Inc.)
4. Comprehensive Analysis of Emissions from the Fluidized-Bed Combustion Miniplant and Bench-Scale Equipment (Exxon Research and Engineering Co.)
5. Comprehensive analysis on other units
6. Preparation of a Sampling and Analytical Manual for Fluidized-Bed Combustion Applications (The Mitre Corporation)
7. Development of improved sampling and analytical techniques (various contractors)

C. Solid and Liquid Waste Disposal

1. Environmental Assessment of Disposal of Solid and Liquid Wastes from Fluidized-Bed Combustion Units (Ralph Stone and Co.)
2. Study of Disposal of Fluidized-Bed Combustion Waste Products (Tennessee Valley Authority)

D. Experimental and Engineering Studies - EA and CTD

1. Experimental and Engineering Support of the Fluidized-Bed Combustion Program (Westinghouse Research Laboratories)
2. Support Studies of Pollutant and Waste Control in Fluidized-Bed Combustion/Regeneration Systems (Argonne National Laboratory) - co-funded with ERDA
3. Miniplant and Bench-Scale Studies in Support of the Fluidized-Bed Combustion Program (Exxon Research and Engineering Co.)
4. Design, Construction and Operation of a Fluidized-Bed Coal Combustion Sampling and Analytical Test Rig (Contractor to be selected/EPA)

E. Paper Studies - EA and CTD

1. The Effect of Experimental Scale on Emissions from Fluidized-Bed Combustion Units (Dow Chemical)
2. Application of Fluidized-Bed Technology to Industrial Boilers: An Economic, Environmental and Energy Analysis (Exxon Research and Engineering Co.) - co-funded with FEA and ERDA
3. Cost Comparison of Commercial Atmospheric and Pressurized Fluidized-Bed Power Plants to Conventional Coal-Fired Power Plant with Flue Gas Desulfurization (Tennessee Valley Authority)

CONTROL OF ATMOSPHERIC POLLUTION BY FLUIDIZED-BED COMBUSTION

G. Vogel, W. Swift, and A. Jonke
Argonne National Laboratory
Argonne, Illinois

The United States Government, in the Clean Air Act, requires that air pollution be kept within acceptable limits. As an example, in the Environmental Protection Agency (EPA) Standards of Performance for New Stationary Sources (1), the maximum allowable emissions from a new coal-burning power plant for SO_2, NO_x, and particulate solids are respectively, 1.2, 0.7, and 0.1 pounds per million British Thermal Units (Btu) of heat, based on a two-hour average. These emission standards are lower in many cases than actual emissions from power plants in pre-Act days according to Cuffe and Gerstle (2), who provided a comprehensive summary of emissions from six types of coal-fired power plants. Since the passage of the Act, companies with existing plants must resort to one of the following to meet local or state regulations for SO_2 emission: use of low-sulfur fuel, use of high-sulfur fuel from which sulfur is removed before combustion, or the use of a scrubber to remove SO_2 from flue gas. The emission of NO_x can generally be controlled by modification of the combustion process in existing power plants, according to Hall and Bartok (3). Particulate solids control in existing plants is a function of the type of solids-removal equipment selected.

Among new techniques for attacking the pollution problem, a concept that is rapidly gaining favor because it appears to be economically attractive is the combustion of fossil fuel in a fluidized bed of sulfur-retaining additive. The national Fluidized-Bed Combustion Program Plan specifies that prototype boilers and heaters shall be ready for industrial and commerical applications within a few years, followed soon by a prototype utility-boiler module. Such equipment is urgently needed as natural gas curtailments continue and affordable oil supplies remain uncertain. The system under development presently appears to ERDA (Energy Research and Development Agency), utilities, and industry to offer cost, efficiency, and reliability advantages over stack-gas scrubbers by avoiding the four to six percent energy loss required for scrubber operation with high-sulfur coal, the cost of scrubbers, and the forced plant outages resulting from scrubber malfunction.

The overall ERDA program in this field involves research, development, and demonstration of both atmospheric-pressure and elevated-pressure concepts. A pilot plant employing the atmospheric-pressure concept is under construction at the Rivesville station of the Monongahela Power Company in West Virginia. The boiler for this pilot plant with a capacity for burning over 10 tons/hr of coal, was designed and constructed by Foster Wheeler Corp. The overall project, being carried out by Pope, Evans and Robbins, Inc., is expected to reach the operating stage around mid-1976. The succeeding stage of development will be a demonstration plant of at least 200 MWe capacity. Preliminary design of such a plant is anticipated to begin in the near future under ERDA or EPRI sponsorship.

The pressurized combustion concept has reached a stage of development such that a proposal for pilot plant construction has recently been accepted by ERDA. The proposal by Curtiss-Wright calls for construction at Woodridge, N.J., of a combustor operating at seven atmospheres pressure with an output of 14 MWe. The pilot plant would provide data for the conceptual design of a 500 MW commercial plant with a calculated efficiency of 40.8%. The project, including operation of the plant, is to extend for a period of 5 1/2 years.

Besides the application to electric power generation, fluidized-bed combustors also have excellent potential for coal-burning industrial and commercial boilers and heaters. ERDA has recently solicited proposals from industry for development and demonstration of various industrial applications, including steam generators and industrial process heaters in full commercial sizes. Proposals are currently being evaluated.

The national development program also calls for construction of several sub-pilot plant facilities for the purpose of providing support to the pilot plants and for developing unique or advanced concepts. Such units will have capacities in the range of 1 to 5 MWe. One such unit, a pressurized Component Test and Integration Facility (CTIF) has been proposed for construction at Argonne National Laboratory (ANL). Another CTIF, for operation at atmospheric pressure, is under design at the Morgantown Energy Research Center. At the Oak Ridge National Laboratory, an experimental unit is under construction to study the application of fluidized-bed combustion to the provision of total energy requirements (heat and electricity) for small communities. In addition to these national facilities, a pressurized process development unit has been authorized for construction in England under sponsorship of the International Energy Agency. Part of the funding for this facility will be provided by ERDA.

Besides the ERDA projects, research and development on fluidized-bed combustion is also being sponsored by the Electric Power Research Institute (EPRI) and by EPA. The EPA program is aimed chiefly at investigation of the environmental control aspects of fluidized-bed combustion.

Argonne National Laboratory (ANL) is one of several organizations participating in a research and development program designed to develop the concept and to eventually demonstrate on a plant scale that the process is economical and meets pollution standards for stationary power sources. The ANL program, which has been under way since 1968, has involved investigations of both atmospheric pressure and elevated pressure concepts. Currently, ANL is conducting a basic research and development program to evaluate the feasibility and potential of fluidized-bed combustion at pressures up to 10 atm Jonke et al. (4), Vogel et al. (5, 6, 7)). Specific objectives include: (1) optimizing the combustion process with respect to sulfur dioxide retention in the fluidized bed of additive and nitrogen oxide suppression in the flue gas; (2) determining the behavior of the system with a variety of coals including lignite and subbituminous coals; and (3) determining trace-element pollutant levels in the flue gas. In this paper, levels of SO_2, NO, and particulate solids in the flue gas obtained in experiments are compared with mandated standards for new power plants. Since no emission standards have been set for trace elements, the distribution of these elements is compared with their distribution in existing power plants.

EQUIPMENT AND INSTRUMENTATION

The experimental equipment and instrumentation consists of a 6-in.-dia fluidized-bed combustor which was operated at a pressure of 8 atm absolute, coal and additive feeders, and flue-gas particulate cleanup equipment. A simplified schematic flowsheet of the equipment is presented in Fig. 1. The flue gas leaving the combustor is sampled and analyzed continuously for NO, SO_2, CH_4, and CO, using infrared analyzers, and for O_2, using a paramagnetic analyzer. Intermittent CO_2 analyses are made by gas chromatography.

MATERIALS TESTED

Combustion experiments have been performed using three different coals (-14 mesh size) and two additives (-14 +100 mesh). The coals tested include a highly caking, bituminous Pittsburgh seam coal (2.82% sulfur) from the Arkwright mine, a subbituminous coal (0.78% sulfur) from the San Juan mine in New Mexico, and lignite (0.53% sulfur) from the Glenharold mine in North Dakota.

Tymochtee dolomite was obtained from C. E. Duff and Sons, Huntsville, Ohio, and contained $\sim$50% $CaCO_3$ and 40% $MgCO_3$. The limestone, obtained from M. J. Grove Lime Company, Stephen City, Virginia, contained $\sim$95% $CaCO_3$ and 1% $MgCO_3$.

COMBUSTION STUDIES USING BITUMINOUS COAL

Statistical Study of the Effects of Bed Temperature, Fluidizing-Gas Velocity, and Ca/S Mole Ratio on Dependent Variables

A series of nine experiments in a 3 x 3 Latin square experimental design (1/3 replicate of 3^3 factorial design) plus two replicate experiments were made. The three levels of the independent variables tested were (1) temperature at 1450, 1550, and 1650°F; (2) Ca/S mole ratio at 1, 2, and 3; and (3) fluidizing-gas velocity at 2.0, 3.5 and 5.0 ft/sec. All experiments were made at a pressure of 8 atm absolute, a 3-ft fluidized-bed height, and 3% oxygen in the dry flue gas, using Arkwright coal and Tymochtee dolomite.

Sulfur Dioxide Emission. Figure 2 illustrates the effects of Ca/S mole ratio, superficial fluidizing-gas velocity, and bed temperature on SO_2 retention. For Ca/S ratios above 2.0, the SO_2 retention is generally greater than 90%. The level of SO_2 in the flue gas increases rapidly, however, with decreasing Ca/S ratio and with increasing gas velocity at low Ca/S ratios. The bed temperature appears to have very little effect. The results indicate that for this coal and additive, it should be possible to operate close to a Ca/S mole ratio of 1.0 and still meet the EPA emission limitation of 1.2 lb of sulfur dioxide per 10^6 Btu (a sulfur retention of $\sim$70%).

Nitrogen Oxide Emission. Nitrogen oxide levels in the flue gas, 270-120 ppm, correspond, respectively, to emissions of 0.40 and 0.15 lb $NO/10^6$ Btu, which are below EPA standards. In Fig. 3, the experimental values of the nitrogen oxide levels in the flue gas are plotted as a function of the Ca/S mole ratio, the only independent variable that appeared to have a significant effect (on the basis of analysis of variance and regression analysis evaluations). The broken lines, connecting data from experiments performed under nominally similar combustion temperatures, suggest a possible temperature dependence, but the results are inconclusive.

The nitrogen oxide levels reported here for combustion at 8 atm are considerably below the 300 to 550 ppm values previously obtained in atmospheric combustion studies (4). This pressure effect on nitrogen oxide emissions has been observed by Wright (8).

Solids Loading in the Flue Gas. Solids loading in the flue gas leaving the combustor (before any particulate removal) varied directly with both the fluidizing-gas velocity and the Ca/S mole ratio, as shown in Fig. 4. At gas velocities of 2, 3.5, and 5 ft/sec, increasing the Ca/S mole ratio from 1 to 3 increased the solids loading by 60, 80, and 125%, respectively. Although these results suggest the desirability of maintaining low Ca/S ratios to minimize solids loading from the additive, high Ca/S ratios could be used at suitably selected gas velocities and sorbent particle sizes. Thus, the loadings quoted here are not representative of what could be achieved. After the flue gas passed through the second cyclone and the final filter, its loading was less than the mandated standard of 0.1 lb/10^6 Btu.

Comparison of Dolomite with Limestone with Respect to Sulfur Retention Capability and NO Level in the Flue Gas at Combustion Temperatures of 1650 and 1750°F

The sulfur retention capabilities of Tymochtee dolomite and Grove limestone were compared at different Ca/S ratios and at fluidized-bed temperatures of 1650 and 1750°F. At these temperatures and a combustor operating pressure of 8 atm, the $MgCO_3$ in the dolomite is calcined to MgO. The $CaCO_3$ does not calcine at 1650°F but does at 1750°F, probably producing a more porous structure. The sulfur retention was better at 1750°F than at 1650°F in experiments with Tymochtee dolomite at different Ca/S ratios (Fig. 5). In single experiments with limestone at a Ca/S ratio of $\sim$1.5, sulfur retention was the same at 1650°F as at 1750°F. Precalcining the limestone before feeding it into the combustor did not improve the sulfur retention capability in a single experiment made at a combustion temperature of 1650°F and a Ca/S mole ratio of $\sim$1.4. The sulfur-retention capability of Tymochtee dolomite at 1750°C was superior to that of Grove limestone, both on a molar basis (Fig. 5) and on a mass basis.

The NO concentrations in the dry flue gas ranged from 130 to 135 ppm (using dolomite) and from 84 to 150 ppm (using limestone). The additive type did not seem to affect NO emission level.

Effect of Percent Combustion Air on Sulfur Retention and on NO Level in the Flue Gas

The effect of the amount of excess combustion air on the sulfur retention capability of Tymochtee dolomite at different Ca/S mole feed ratios was evaluated using a bed temperature of 1650°F and a fluidizing-gas velocity of 4.5 ft/sec. Excess air levels were 17, 44, and 75%. At these levels no meaningful and consistent effect on the sulfur-retention capability of dolomite was found, as shown in Fig. 6.

The NO concentration in dry flue gas was found to increase with oxygen concentration, as expected. At ~3, 6, and 9% oxygen in the dry flue gas, the NO concentrations were 160, 200, and 220 ppm, respectively.

COMBUSTION STUDIES USING LOW-SULFUR SUBBITUMINOUS AND LIGNITE COALS

Experiments were made to determine whether any difficulties would be encountered in processing a San Juan subbituminous coal with a high ash content of 17% and a Glenharold mine lignite with a low heating value of 7,625 Btu/lb. The nominal operating conditions for the two experiments were a bed temperature of 1550°F, a fluidizing-gas velocity of 3.5 ft/sec, an O_2 concentration of 3% in the dry flue gas (~15% excess air) and a Ca/S mole ratio of 1.

Sulfur Dioxide Retention

The SO_2 levels of 250 and 120 ppm observed for the combustion of the subbituminous and lignite coals, respectively, correspond to emissions of 0.45 and 0.21 lb $SO_2/10^6$ Btu. The combustion of Arkwright bituminous coal under similar operating conditions would have a projected SO_2 emission of 610 ppm or 1.2 lb $SO_2/10^6$ Btu. The above emissions represent SO_2 retentions of approximately 72, 72, and 85% for the bituminous, subbituminous, and lignite coals, respectively. The somewhat higher retention reported for the lignite experiment suggests that calcium in that coal may be an active agent in helping to retain SO_2 during combustion.

Nitrogen Oxide Emissions

The NO levels of 150 ppm and 130 ppm, respectively, for the combustion experiments with the subbituminous and lignite coals correspond to emissions of 0.19 and 0.18 lb $NO_2/10^6$ Btu. The projected emission for the bituminous coal (140 ppm) under similar conditions is also 0.19 lb $NO_2/10^6$ Btu.

TRACE ELEMENT DISTRIBUTIONS

Environmentalists and researchers are becoming increasingly concerned that trace elements emitted from fossil-fueled power plants, incinerators, and industrial processes may have significant adverse environmental and health impacts. Although a substantial fraction of the trace elements present in coal during combustion is retained with the fly ash removed by emission control devices, significant quantities of trace elements (such as mercury) may still be emitted as vapors or in association with submicron size particles that are not efficiently removed by present-day devices. Recent investigations have also demonstrated that several trace elements (such as lead, cadmium, arsenic, and nickel) preferentially concentrate in the smallest particles emitted from conventional coal-fired power plants.(9-11)

Since fluidized-bed combustion is carried out at temperatures (1550-1750°F) well below those of conventional power plants and in the presence of adsorbent for sulfur dioxide removal, an investigation was made to evaluate the potential of fluidized-bed combustion for reducing trace-element emissions as compared with conventional combustors. A convenient basis for evaluation was to make mass balances around the ANL 6-in.-dia fluidized-bed combustor for comparison with similar data reported for large, conventional coal-fired power plants.

Mass balances were made for the following trace and minor elements: Hg, F, Be, Pb, As, Br, Co, Cr, Fe, K, La, Mn, Na, and Sc. Wet chemical techniques were employed to measure the concentrations of the four trace elements of primary interest in the investigation: mercury, lead, beryllium, and fluorine. Mercury and lead were analyzed by atomic adsorption, beryllium by fluorimetry, and fluorine by specific ion electrode. The concentrations of the remaining trace elements measured were obtained by neutron activation analysis.

Nominal conditions for two experiments were a bed temperature of 1550°F, 10-atm pressure, and 4% O_2 in the off-gas, as compared with values of 1650°F, 8 atm, and 3% O_2 for two other experiments. To assess the effects of additive, in one experiment at each set of conditions coal was combusted in a fluidized bed of alumina; in the other experiment, coal was combusted in a fluidized bed of dolomite.

Results of the mass balance calculations are presented in Table 1. The first two lines in Table 1 list mass balances for mercury and fluorine based on both solids and flue gas analyses. The mercury balances, which exhibited an average recovery of only 38%, are particularly disappointing. The fluorine balances of 120 and 110% recovery for the experiments at 1550°F are reasonably acceptable values; the recoveries of 180 and 240% for the experiments at 1650°F are unaccountably high.

The remainder of Table 1 lists the material balances, based on solid samples only, for those elements (including mercury and fluorine) for which sufficient analytical data were available. Retention of the relatively volatile elements, mercury, arsenic, fluorine, and bromine, in the solids indicates that fluidized-bed combustion may reduce the emissions of these elements.

The average retention of 23% for mercury in the solid effluents from the combustor (Table 1) compares favorably with the 10% retention reported by Billings et al. (12) for a large conventional coal-fired power plant. Klein et al. (11) reported that mercury remains almost completely in the gas phase. The measured retention of 85% for arsenic compares favorably with the arsenic recovery, reported by Klein et al. (11), of only 40 to over 100% for a mass balance around a conventional 290-MWe, cyclone-fed boiler. Similarly, Attari (13) estimated only 35% retention of arsenic in the solid effluents from the Illinois Institute of Gas Technology's HyGas (high-Btu coal gasification) pilot plant.

The average retentions of fluorine and bromine in the combustion experiments with dolomite (59 and 36%, respectively) were compared with those in the combustion experiments in an alumina bed (14 and 0%, respectively). This indicates that the additive used for sulfur dioxide removal is also effective in reducing the emissions of these two elements. In comparison, Klein et al. (11) reported that only 10% of the bromine was recovered in the ash from a conventional boiler.

Seven of the remaining ten elements reported on (Mn, Co, Fe, K, La,Na, and Sc) had material balances of 100 ± 10%, indicating (within analytical accuracies) essentially no losses by volatilization. The relatively low recoveries of beryllium and chromium are suspect since (1) complete recoveries of chromium have been reported for coal-processing units operated at much higher temperatures and (2) beryllium is reportedly less volatile than chromium (14). Except that there was one unaccountably high recovery for manganese, this element also exhibited a recovery of 100 ± 10%.

The significance of these results is emphasized in Table 2, which compares the project trace element emissions from conventional and fluidized-bed combustion systems, based on currently available mass balance data. With the exception of the projected emissions for chromium, the emissions from fluidized-bed combustion are consistently as low as or lower than those projected for conventional combustors.

The trace-element data were further analyzed to qualitatively assess the relation of concentration to particle size in the fly ash. For the two combustion experiments carried out in a fluidized bed of alumina, the concentrations of the trace elements in the coal and fly ash samples from successive stages of gas-particle separators (primary cyclone, secondary cyclone, and filter) were adjusted to a combustible matter-free basis and then normalized against an arbitrary reference concentration (concentration of the element in the coal or primary ash). The results of this analysis for seventeen trace and minor elements are shown in Fig. 7.

For several elements (such as Ba, Co, La, Sb, Sc, and Ta), there were marginal (possibly insignificant) tendencies of concentration to increase with decreasing particle size. Of these elements, only antimony is acknowledged to concentrate strongly in the finer fly ash from conventional plants (8-11); barium, cobalt, lanthanum, scandium, and tantalum have exhibited marginal preferential partitioning by particle size in fly ash (11). Lead and chromium, which show no tendencies to increase with decreasing particle size in this study, have exhibited strong and moderate (8-11) enrichment, respectively, in the fly ash from conventional boilers. The lower combustion temperatures of fluidized-bed combustion may be effective, therefore, in reducing the enrichment of trace elements in the finer ash particles.

ACKNOWLEDGMENTS

We gratefully acknowledge support of this program by the Energy Research and Development Administration and by the Environmental Protection Agency.

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Figure 1. - Simplified equipment flowsheet of ANL fluidized-bed combustor system.

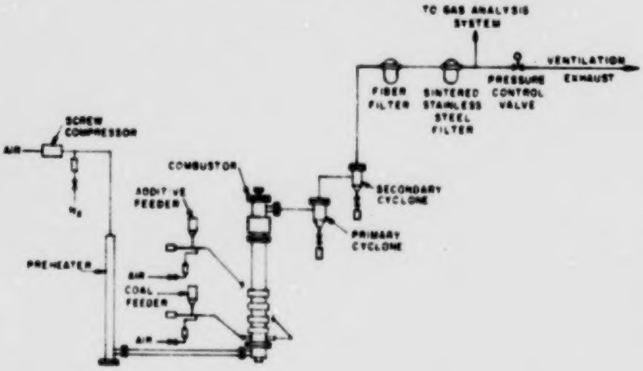

TO GAS ANALYSIS SYSTEM
VENTILATION EXHAUST
FIBER FILTER
SINTERED STAINLESS STEEL FILTER
PRESSURE CONTROL VALVE
SCREW COMPRESSOR
AIR
N_2
COMBUSTOR
ADDITIVE FEEDER
SECONDARY CYCLONE
PRIMARY CYCLONE
PREHEATER
AIR
COAL FEEDER
AIR

Figure 2. - Effect of bed temperature, fluidizing gas velocity, and Ca/S mole ratio on sulfur retention in the bed during combustion. Arkwright coal and Tymochtee dolomite.

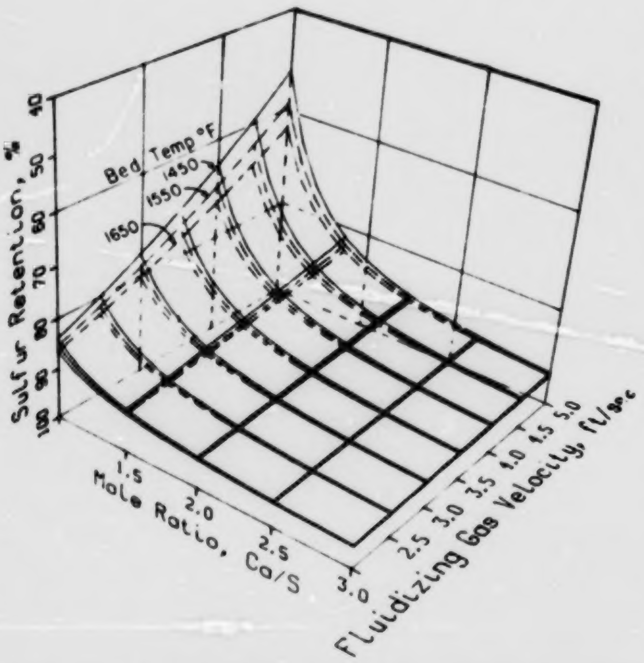


Figure 3. - NO concentration in flue gas as a function of Ca/S mole ratio

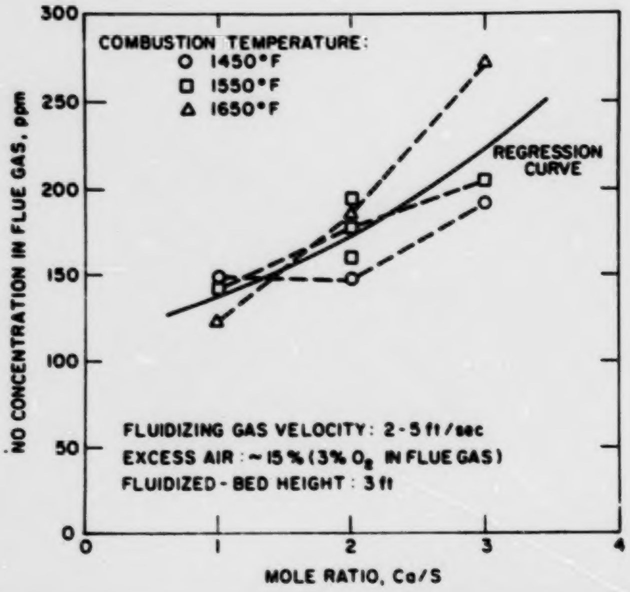


Figure 4. - Solids loading of flue gas leaving the combustor.

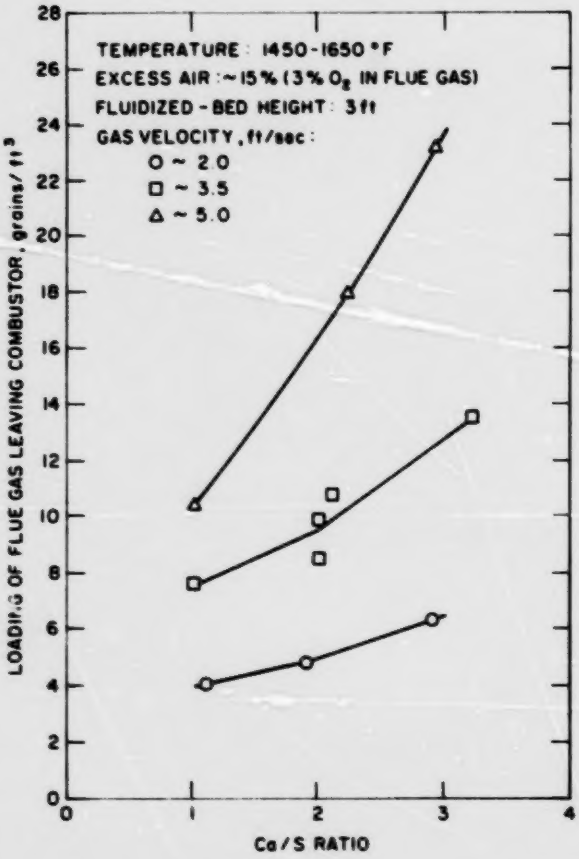


Figure 5. - Sulfur-retention capabilities of additives compared, molar basis

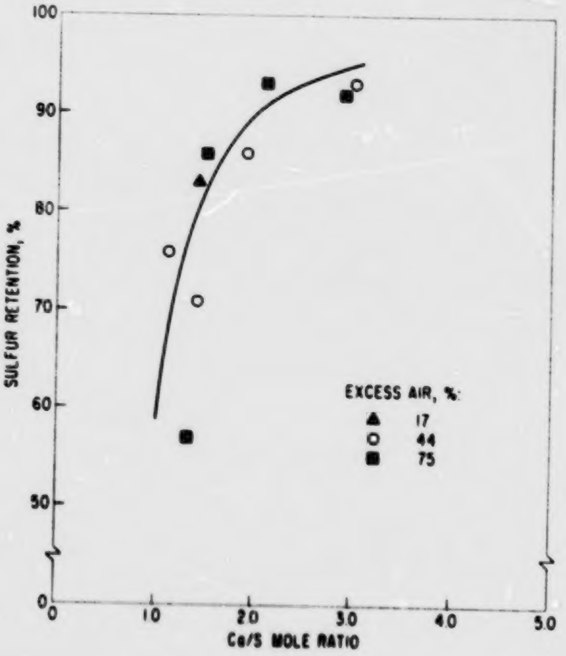


Figure 6. - Effect of excess combustion air on sulfur retention, Tymochtee dolomite.

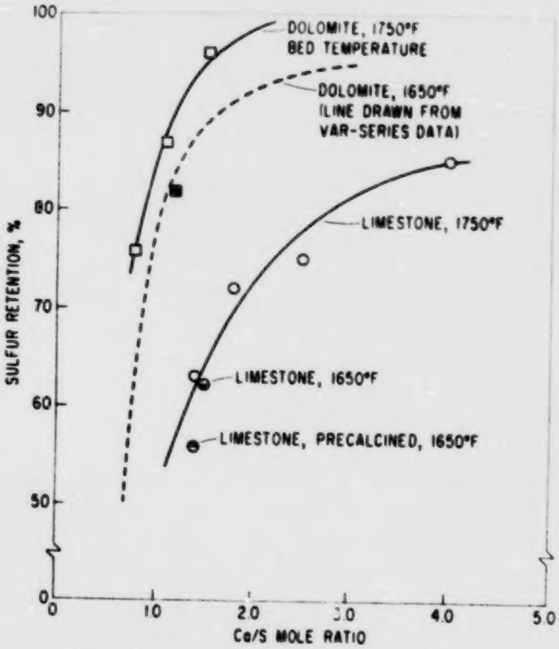
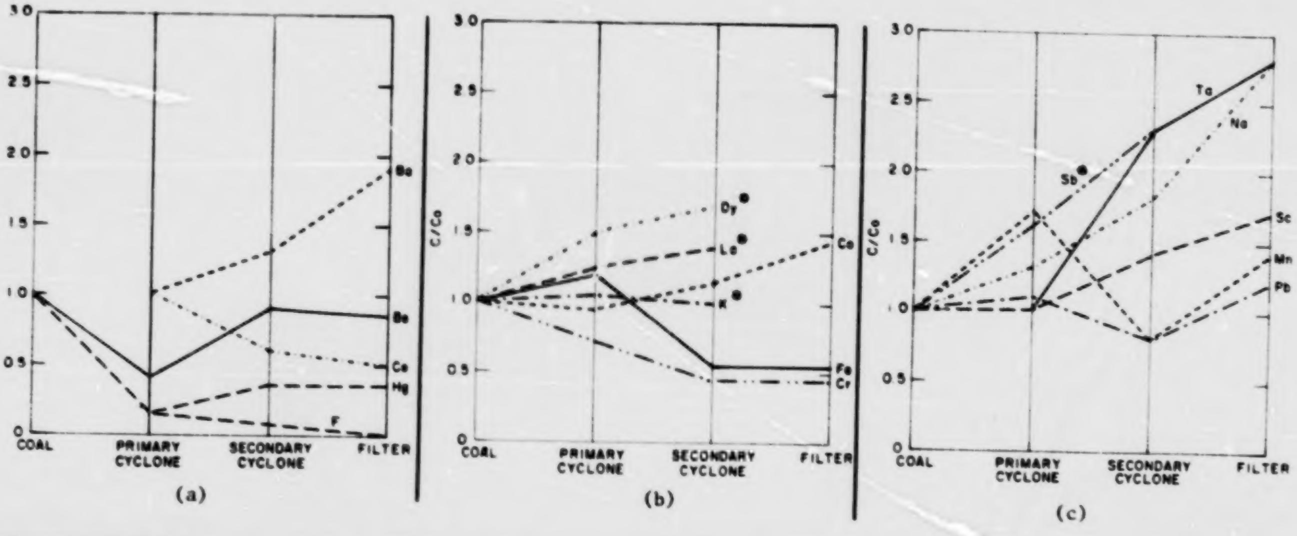


Figure 7. - (a), (b), and (c) - Normalized concentrations of trace elements as a function of sample indicating the relative enrichment of trace elements between coal and ash samples and among samples of ash of successively finer particle size. Data pertains to combustion in a fluidized bed of alumina at 1550°F (indicated by asterisk) or 1650°F.



(a)

(b)

(c)

Table 1. - Mass Balances for Trace and Minor Elements Around ANL's 6-in.-dia, Pressurized, Fluidized-Bed Combustor.

Element	Recovery[a], %				
	Combustion in Alumina Bed		Combustion in Dolomite Bed		Average[b]
	1550°F	1650°F	1550°F	1650°F	
Mass Balances Based on Solids and Flue-Gas Analysis					
Hg	56	29	43	25	38
F	120	180	110	240	160
Mass Balances Based on Solids Analysis Only					
Hg	37	26	9	20	23
F	5	23	62	56	36
Pb	110	120	78	95	100
Be	63	56	71	87	69
As	85	I[c]	85	>83	85
Br	0	I	36	I	18
Co	79	100	88	96	91
Cr	27	64	83	120	74
Fe	92	120	95	92	100
K	120	I	77	74	90
La	120	>74	89	I	104
Mn	110	170	110	I	130
Na	79	120	85	100	96
Sc	110	110	83	88	98

[a] Percent of element entering combustor accounted for in product steams.

[b] Average recovery for experiments in which a balance was determined.

[c] I means indeterminate due to incomplete concentration data for some samples.

Table 2.- Projected Emissions of Trace Elements from Conventional and Fluidized-Bed Combustors Expressed as a Percentage of the Element Entering the System.

Element	Conventional Combustion[a]	Fluidized-Bed Combustion
Hg	90-100	80
F	90-100 (estimated)	40
Br	90-100	65
As	0-60	15
Pb	10	0-20
Be	Not Available	20-40
Sc	10	0
Cr	0	25
Co	10-20	0-20
Na	0-10	5
K	0-10	10
Fe, La, Mn	0	0

[a] Projected from data in the literature (10-12) on trace-element emissions from conventional power plants.

COST COMPARISON OF COMMERCIAL ATMOSPHERIC AND PRESSURIZED FLUIDIZED-BED POWER PLANTS TO A CONVENTIONAL COAL-FIRED POWER PLANT WITH FLUE GAS DESULFURIZATION

John T. Reese
Tennessee Valley Authority
Chattanooga, Tennessee

INTRODUCTION

Fluidized-bed combustion (FBC) is one of the most promising advanced combustion processes to be studied since development of pulverized coal combustion in the 1920's. Not only does the process offer the potential for reducing capital cost of equipment and for improved thermal efficiencies, but it can also provide a more environmentally acceptable method for burning coal.

Because of the promise which FBC holds, extensive research and development efforts are under way to bring the concept to commercial reality. Among those active in the field are the Energy Research and Development Administration (ERDA) which has lead responsibility for Government-sponsored efforts in FBC and the Environmental Protection Agency (EPA) which is evaluating and attempting to minimize the environmental impact of FBC systems. Major R&D programs are under way at Argonne National Laboratory; Babcock and Wilcox Company; Combustion Power Corporation; Combustion Systems, Ltd.; Curtiss Wright Corporation; Electric Power Research Institute; Exxon Research and Engineering Company; Foster Wheeler Corporation, General Electric Company; Pope, Evans and Robbins, Inc.; Westinghouse Electric Corporation; and a number of other organizations.

At the present time, a variety of flue gas desulfurization (FGD) processes are the only technology being applied to new fossil-fired power plants for meeting EPA New Source Performance Standards (NSPS). The lime/limestone system is probably the best developed and most widely applied of all the FGD processes.

EPA is sponsoring a project to compare the cost of commercial atmospheric (AFB) and pressurized (PFB) power plants to a conventional coal-fired (CCF) power plant with FGD. It is envisioned that the project will provide an assessment of the economic potential of FBC over a conventional power plant with FGD for meeting environmental standards and to identify the areas where significant economic gains can be made by concentrated R&D.

The objectives of the project are to develop conceptual design and comparative capital and operating costs for each of the following new power plants:

1. A CCF steam power plant with flue gas desulfurization
2. An AFB steam power plant
3. A PFB combined cycle power plant

The project draws on a variety of organizations. The performing agency is the Tennessee Valley Authority. Fluidized-bed combustor designs, along with capital and operating cost estimates, are being utilized from ongoing work under the direction of the National Space and Aeronautics Administration (NASA). This effort is called the Energy Conversion Alternative Systems (ECAS) study and is sponsored by ERDA and the National Science Foundation. For ECAS work being incorporated in this program, General Electric Company is contractor in charge of energy conversion system and overall plant design, Foster Wheeler Energy Corporation has responsibility for furnace designs, and Bechtel Corporation will provide design of the FGD system and balance of plant systems. Upon completion of design and cost estimates, TVA will integrate the information developed into a single report which compares on a common basis using standard utility practice the cost of the three plants.

POWER PLANT CONCEPTUAL DESIGNS

1. Technical Discussion

The accuracy of cost estimates for a particular system is in direct proportion to degree of maturity of the technology. An illustration of this fact is evident in estimates made for FGD systems. In 1969 the projected capital cost of a limestone wet scrubbing system was \$7.75/kW.[1] As development progressed and real plants were engineered and constructed, 1972 capital costs for the same process system were estimated to be \$40.75/kW[2]--greater than a fivefold increase over the earlier value.

Similarly low capital and operating cost estimates could occur in this program unless allowance is made for those areas where technical uncertainties exist. Several major design issues are not fully resolved in each of the three power plant concepts.

Some of the features in FBC which require further definition are:

Solids handling and injection systems

Arrangement of heat transfer surface in fluid beds

Fluid-bed startup systems

Control and load following capability

Mechanical design of dampers for combustion air control, heat transfer surface supports, and other hardware subjected to large temperature gradients

Optimum bed temperature for SO_2 removal

Optimum stoichiometry

Regeneration of spent absorbent

Hot particulate cleanup for PFB effluent

Corrosion-erosion of gas turbine parts

Hot bed material handling and cooling system

Optimum exit gas temperature

Of particular concern is hot particulate cleanup for PFB power plants. The efficiency of mechanical dust collectors drops off rapidly below five microns. In order to provide corrosion-erosion protection for the gas turbine, it is necessary that particulates in the 1-5 micron range be removed. High temperature filters may provide the required degree of particulate removal; however, the attendant material and structural specifications may present a problem. Also, at combustion temperatures, alkali metal compounds have appreciable vapor pressure. Filter devices may not provide adequate protection. If this occurs, resistance to alkali metal compounds will have to be designed into the gas turbine materials.

Longstanding commercial application of CCF plants reduces uncertainties for this case to a minimum; however, some degree of uncertainty remains in the area of NO_x control and some aspects of the FGD system. Staged combustion experiments have demonstrated the capability of such operation to reduce NO_x emissions below NSPS.[3] However, carefully monitored corrosion tests indicate staged combustion with many current boiler designs may cause serious furnace tube wall corrosion.[4] It is likely that attainment of NO_x emission standards will have to be achieved through a burner or furnace design which circumvents the corrosion problem posed by staged combustion operation.

As with FBC plants, disposal of SO_2 absorbent/ash wastes from conventional plants with FGD poses an environmental problem and adds an economic penalty to the plant. Development of a suitable regeneration scheme which produces a salable byproduct and returns sorbent to the system would provide for an improvement in economics. Improved mist elimination techniques, reduction of scaling in scrubbers, and improved design of flue gas reheat systems have been accomplished; however, commercial experience will undoubtedly identify areas which require further effort.

2. Program Discussion

Conceptual designs are nearing completion and most major design specifications have been selected for each of the cases being studied.

Conceptual design of the CCF plant is shown schematically in figure 1. The plant has a nominal rating of 870 MW electrical. The steam generator is a single furnace unit 74.5 feet wide by 46 feet deep by 185 feet high. It is designed to produce 7115 x 10^6 lb/h supercritical steam at 3500 psi and 1000°F with reheat to 1000°F. Pulverized coal, sized 70 percent < 200 mesh, is fired through two sets each of 16 horizontally opposed burners. Burners and furnace are designed to limit NO_x emissions to meet EPA NSPS.

The furnace heat input rate is 8128 x 10^6 Btu/h at full load. Design heat transfer coefficients are 20 Btu/h-ft^2-°F in the radiant section of the boiler and 13 Btu/h-ft^2-°F for convection surfaces. Peak furnace gas temperature is approximately 3500°F.

Flue gas leaving the boiler air heater enters a 99 percent efficient electrostatic precipitator. It is then pumped by the induced draft fan through four parallel trains, each containing a single-stage, packed tower scrubber. Scrubbing medium for the flue gas is a slurry of calcium hydroxide (lime). Sulfur dioxide is scrubbed out to a level conforming to the EPA NSPS of 1.2 lb SO_2 per million Btu heat input. Flue gas leaves the scrubber at 125°F and is reheated to 250°F by blending with hot air. Hot air is supplied by passing over steam coils. An alternate exit gas reheat temperature of 175°F will be considered to reflect the gain in efficiency to be expected in the event acid dewpoint of the flue gas will permit reduction to this lower temperature.

Coal is delivered, handled, and prepared in the conventional manner. Limestone is delivered to the plant and calcined in a rotary kiln to supply lime for flue gas scrubbing.

The AFB power plant schematic is shown in figure 2. Steam conditions are 3500 psi, 1000°F/1000°F. The plant consists of four AFB steam generator modules with a nominal capability of 230 MW electrical each. The four modules supply steam to a single turbogenerator with a rating of 920 MW electrical.

Arrangement and distribution of steam generating surface between beds are not yet clearly defined and need further study. Each steam generator module consists of six conventional fluidized beds operating at 1550°F and one carbon burnup cell operating at 2000°F. Heat released in each conventional fluid-bed module is approximately 2012 x 10^6 Btu/h. Ninety percent of the heat is released in main combustion cells with an additional 10 percent being released in the carbon burnup cell. Of the heat released in the main beds, 90 percent release is allowed for in the bed and 10 percent ±5 percent in the freeboard above the bed. Overall heat transfer coefficient for the beds is 40 Btu/h-ft^2-^{o}F. Expanded bed depth during operation is four feet.

Coal is delivered to the plant by rail, stored in a pile, and reclaimed as required. From reclaim, coal is transported by belt conveyor to a coal storage silo. Coal is withdrawn on a continuous basis from the silo and dried to provide proper screening and transport properties. The dried coal is crushed to ½ inch x 0 inch.

Limestone is delivered to the plant by rail, stored in a pile, and reclaimed as required. Preparation for injection is similar to coal, except limestone is crushed to 1/8 inch x 0 inch. After being crushed to size, the coal and limestone streams are transported in separate belt conveyors and bucket elevators to two-hour holding hoppers positioned above each steam generator module. Coal and limestone are withdrawn from these hoppers at metered rates and blended together to provide a 2:1 calcium/sulfur ratio. Rotary air lock valves are used to subdivide the blended mixture into seven separately controllable streams which cascade from virbrating tables possessing four downcomer pipes to vibrating tables which feed 12 injector pipes. This arrangement allows each blended stream to be subdivided into 48 separate streams for injection into the bed. A bypass stream ahead of the coal-limestone blender feeds limestone directly to the carbon burnup cell feed tables.

After combustion and sulfur sorption, coal ash and spent sorbent are withdrawn from the fluid bed through a high-temperature air lock valve and transported to a spent solids cooler. Solid material elutraited from the AFB beds is removed from the gas stream in two stages. The first stage of cleanup consists of multitube cyclones with electrostatic precipitators providing the final stage of cleanup. Solid material captured in the cyclones is returned to the process by injection into the 2000^{o}F carbon burnup cell. Ultimate solids disposal is in a lined storage pond.

High-temperature tubular air preheaters are provided to limit the cyclone/precipitator gas inlet temperatures to a 730-850^{o}F range. Low-temperature regenerative air preheaters follow and reduce the gas to an exit temperature of 250^{o}F.

The PFB combined cycle power plant schematic is shown in figure 3. As with the CCF and AFB plants, steam conditions are 3500 psi, 1000^{o}F/1000^{o}F. The plant has a nominal rating of 920 MW electrical. The boiler consists of four PFB steam generating modules operating at a gas side pressure of 10 atmospheres. Each of the modules supplies 1650^{o}F gas to a gas turbine which produces 46 MW electrical of power. The four modules supply steam to a single turbogenerator with a nominal rating of 736 MW electrical.

Each steam generator module consists of six conventional fluidized beds operating at 1650^{o}F and one carbon burnup cell operating at 2000^{o}F. Like the AFB plant, arrangement and distribution of steam generating surface between beds is not yet clearly defined and needs further study. Heat released in each conventional fluid bed module is approximately 1968 x 10^6 Btu/h. Ninety-five percent of the heat released occurs in the main beds with an additional five percent in the carbon burnup cell. Overall heat transfer coefficient for the beds is 50 Btu/h-ft^2-^{o}F. Expanded bed deptn during operation is 8 feet.

Coal is delivered to the plant by rail, stored in a pile, and reclaimed as required. From reclaim, coal is transported by belt conveyor to a coal storage silo. Coal is withdrawn on a continuous basis from the silo and dried to a surface moisture of less than 1 percent as required by the fuel injection system. The dried coal is crushed to ½ inch x 0 inch and transported to a surge hopper supplying the fuel injection system.

Limestone is delivered to the plant by rail, stored, reclaimed, and prepared for injection in a manner similar to coal preparation. Coal and limestone are fed separately to the boilers by a pressurized, pneumatic injection system. The limestone feed rate is set to provide a 2:1 calcium/sulfur ratio.

After combustion and sulfur sorption, coal ash, and spent sorbent are withdrawn from the process and transported to a spent solids cooler. Solids disposal is in a lined storage pond.

Flue gas and elutriated solids from the fluid beds pass through two-stage cyclone collectors followed by granular bed filters. Solid material captured by the cyclones is transported to the carbon burnup cell.

Flue gas leaving granular bed filters enters the gas turbine at 138 psia and 1600^{o}F. Gas leaves the gas turbine at 15.42 psia and 865^{o}F and passes over a low level economizer before leaving the stack at a temperature of 250^{o}F.

RESOURCE ALLOCATION

Funds for this project are supplied through interagency energy supplement funds. Project funding is $150,000 with essentially the total amount committed to FY 1976 and transition quarter 1976.

INTERAGENCY PARTICIPATION

EPA is conducting a contract research and development program valued at about $4 million in fiscal year 1976 aimed at complete environmental characterization of the fluidized-bed coal combustion process.[5] This program is being conducted in coordination with the effort being directed by ERDA to develop fluidized-bed coal combustion technology. The project to compare costs of commercial AFB and PFB power plants to a conventional plant with FGD being carried out by TVA is designed to provide an assessment of the economic potential of these alternative methods for utilizing coal in an environmentally acceptable manner.

CONCLUSIONS

Upon completion, this study will provide a useful guide for assessing the advantages of FBC as compared with flue gas desulfurization. It will identify major design features in which further development could improve economics of the process. This, in turn, will help provide a better definition of R&D priorities.

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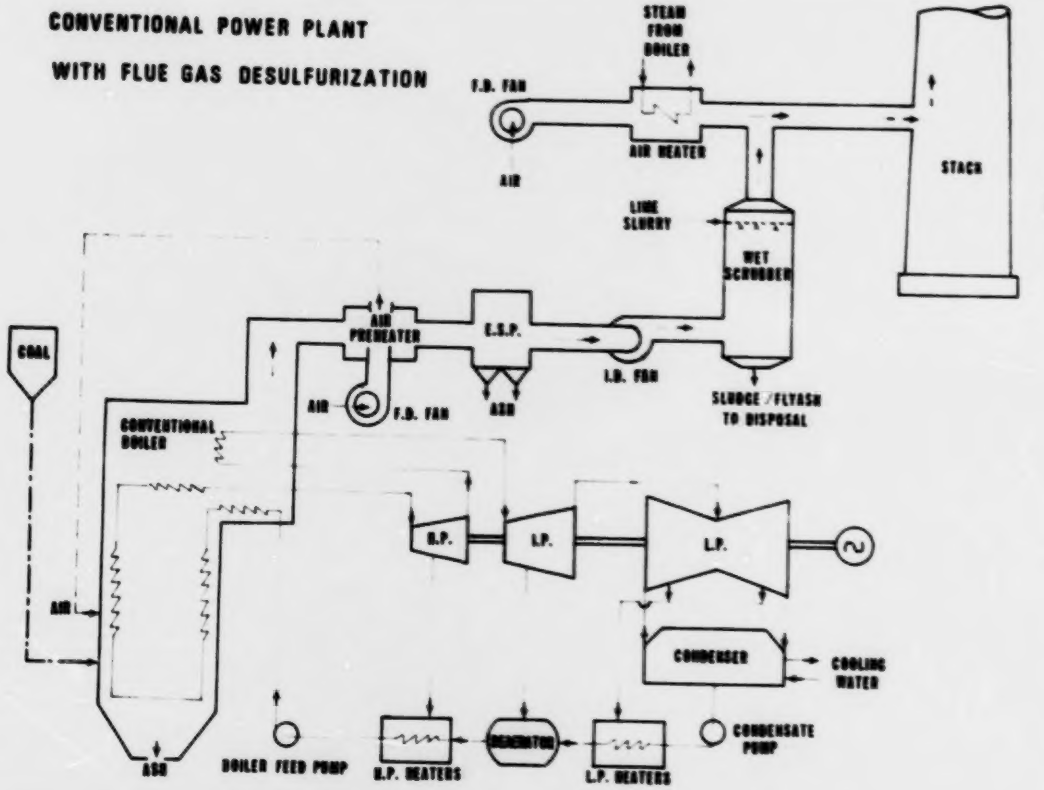
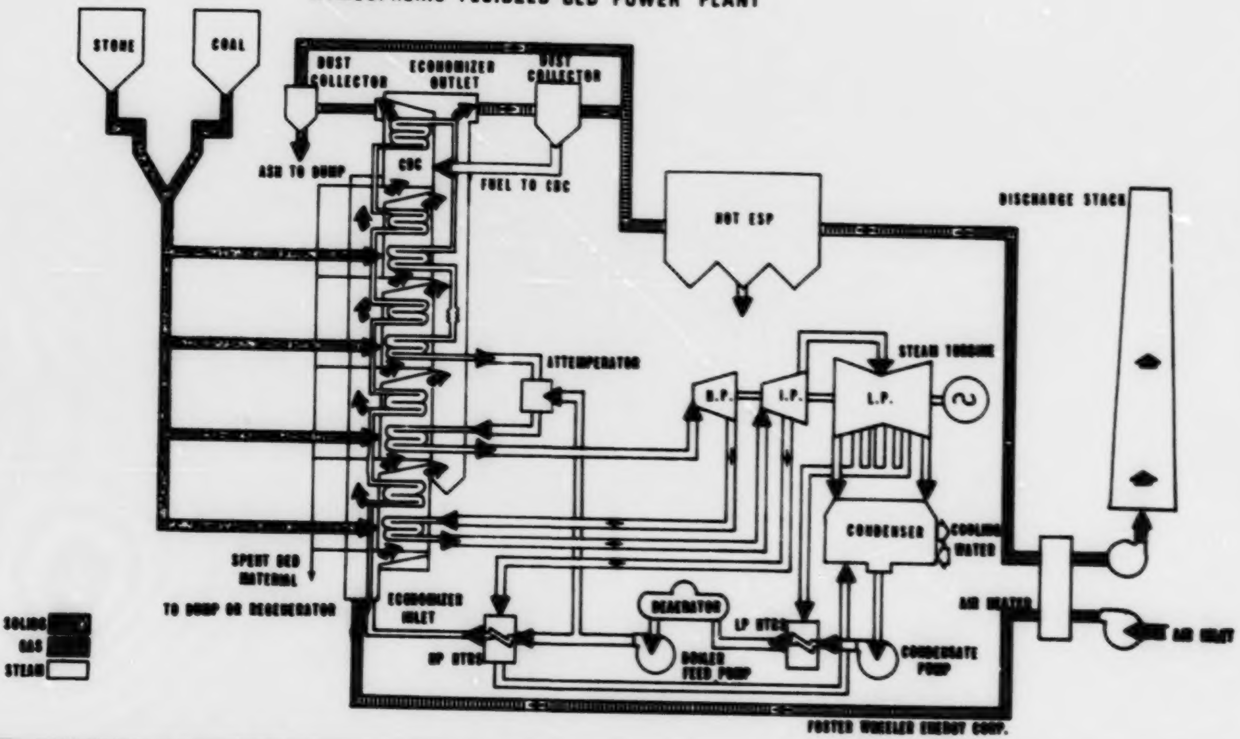
Figure 1



CONVENTIONAL POWER PLANT WITH FLUE GAS DESULFURIZATION

STEAM FROM BOILER
F.D. FAN
AIR
AIR HEATER
STACK
LIME SLURRY
WET SCRUBBER
COAL
AIR PREHEATER
E.S.P.
AIR
F.D. FAN
ASH
I.D. FAN
SLUDGE / FLYASH TO DISPOSAL
CONVENTIONAL BOILER
H.P.
I.P.
L.P.
AIR
CONDENSER
COOLING WATER
ASH
BOILER FEED PUMP
H.P. HEATERS
DEAERATOR
L.P. HEATERS
CONDENSATE PUMP

Figure 2



ATMOSPHERIC FLUIDZED BED POWER PLANT

STONE
COAL
DUST COLLECTOR
ECONOMIZER OUTLET
DUST COLLECTOR
ASH TO DUMP
CBC
FUEL TO CBC
HOT ESP
DISCHARGE STACK
ATTEMPERATOR
STEAM TURBINE
H.P.
I.P.
L.P.
CONDENSER
COOLING WATER
SPENT BED MATERIAL
TO DUMP OR REGENERATOR
ECONOMIZER INLET
DEAERATOR
LP HTRS
HP HTRS
BOILER FEED PUMP
CONDENSATE PUMP
AIR HEATER
AIR INLET
SOLIDS
GAS
STEAM

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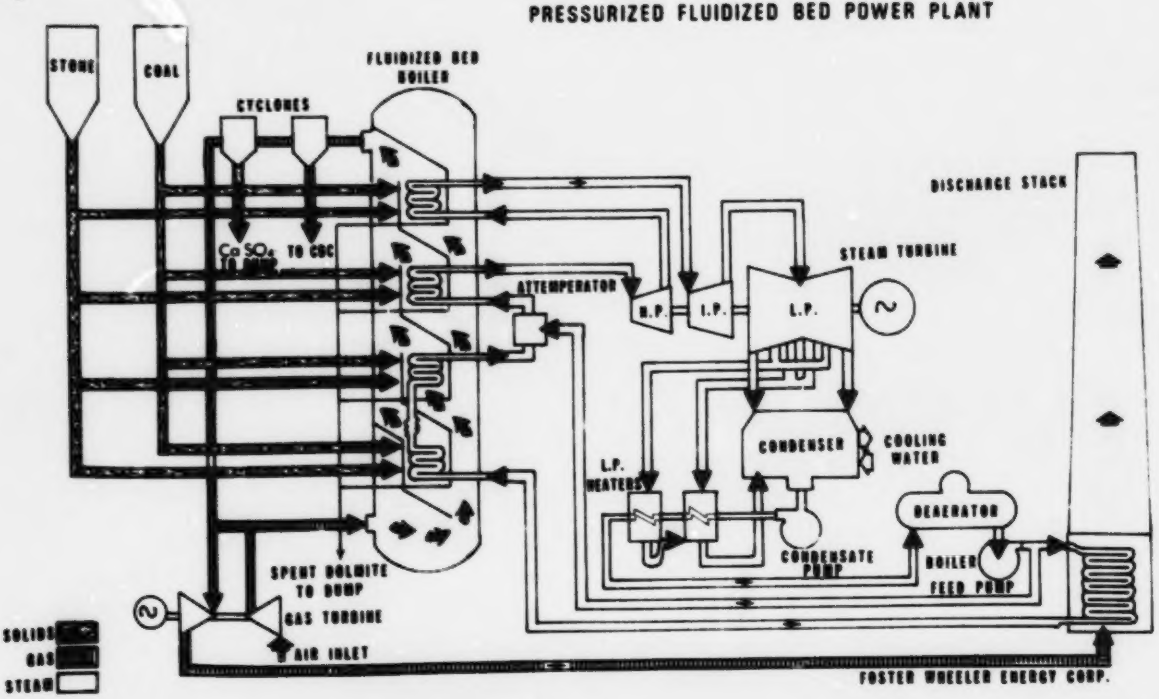
Figure 3

PRESSURIZED FLUIDIZED BED POWER PLANT


STONE
COAL
CYCLONES
FLUIDIZED BED BOILER
CaSO₄ TO DUMP
TO CBC
ATTEMPERATOR
SPENT DOLMITE TO DUMP
GAS TURBINE
AIR INLET
SOLIDS
GAS
STEAM
H.P.
I.P.
L.P.
STEAM TURBINE
L.P. HEATERS
CONDENSER
COOLING WATER
CONDENSATE PUMP
DEAERATOR
BOILER FEED PUMP
DISCHARGE STACK

FOSTER WHEELER ENERGY CORP.

ASSESSMENT AND CONTROL OF ENVIRONMENTAL CONTAMINATION FROM TRACE ELEMENTS IN COAL PROCESSING WASTES

E. M. Wewerka, J. M. Williams, and P. L. Wanek
University of California
Los Alamos Scientific Laboratory
Los Alamos, New Mexico

INTRODUCTION

Coal, as mined, contains a great deal of extraneous rock and mineral matter. The inorganic constituents often represent as much as 30 to 40% of run-of-the-mine products. These rock and mineral impurities are expensive to ship, dilute the caloric content of the coal, and produce undesirable gaseous and particulate pollutants when the coal is burned or utilized. Consequently, much of the more highly mineralized coals-about one-half of the total mined in the U.S.-is processed to remove some of the unwanted mineral and rock materials. This is done by various preparation methods, which utilize, for the most part, density or flotation techniques to separate the heavier mineral components from the lighter coal. The discarded rock, mineral and coaly matter from coal preparation facilities, together with other coal-mine refuse, comprise the gob piles or culm banks which are scattered over thousands of surface acres in coal-producing regions.

Recent estimates are that nearly two billion tons of carbonaceous mineral wastes have been accumulated in the U.S. as a result of coal preparation and mine development.(1) In addition, another 100 million tons or so is being added each year, and annual production of waste is certain to increase as the consumption of coal increases.(1) This huge mass of material has always been considered a nuisance tied to the production of cleaner coal, and more often than not, coal preparation wastes have simply been discarded at a convenient place in the countryside to be left to the processes of nature.

Coal waste is not only a problem for the coal producer, who must dispose of it, often at considerable expense, but frequently these discarded wastes represent a formidable hazard to the environment or to public health or safety.(1,2) There have been many cases where dams or gob piles constructed of coal wastes have collapsed with tragic consequences for the people living nearby. The 1972 disaster at Buffalo Creek, WV, and the tragedy at Aberfan, Wales, a few years ago are vivid examples. Also, weathering and leaching of coal waste dumps produce highly mineralized and often acidic solutions which drain into surrounding areas.(2) These places suffer from severe losses of soil fertility and a badly degraded aquatic environment. Chemical degradation and oxidation of coal wastes can also produce sufficient heat to ignite the waste dump.(2) Presently, several hundred gob piles are burning, and these are an appreciable source of atmospheric pollution.(2)

In recent years, attempts have been made to circumvent some of the major environmental problems associated with coal refuse disposal.(3) To prevent exposure to water and air, waste materials have been crushed, carefully compacted, and then covered with top soil or sealed with sludge, clay or other materials. Often coal debris is sealed into abandoned mines or placed in stripped out areas. Substantial effort to stabilize waste piles and banks by revegetation has been undertaken, and much work has gone into methods of neutralizing acidic effluents. Although these measures appear to solve the immediate problem of stabilizing the structures of gob piles and they seem to slow geological processes somewhat, it is not clear how effective they will prove to be in the long run.

In addition to these well recognized problems, another potential environmental hazard is beginning to gain attention. Coals, and undoubtedly coal wastes, contain a broad array of trace or minor elements.(4) Many of these trace elements, such as lead, cadmium, arsenic, selenium, mercury, etc. are of considerable concern because of the low tolerances of plants and animals for them.(5) Undoubtedly many of these trace elements are carried into the environment by aqueous transport and vaporization. Although the relative amounts of these components per unit of waste is usually small, the total absolute amount of each available in a large waste bank could cause grave consequences in water, soil or air if they were concentrated by natural processes. (Alternatively, of course, this suggests that it may be possible to recover useful quantities of minor materials from existing waste dumps.)

Several notable investigations of the composition of coal cleaning wastes, and the nature of the drainage from waste disposal areas have been reported.(2,6,7) These have been concerned mainly with the major mineral components and dissolved materials from them. No comprehensive assessment of the chemistry and mineralogy of trace elements in coal refuse materials has been done. Therefore, little is known about the behavior of the various trace elements in coal wastes under conditions of weathering, burning and leaching. It is the objective of the EPA-supported research program now underway at Los Alamos Scientific Laboratory (LASL), and described herein, to define potential environmental problems from trace elements in coal processing wastes and develop suitable pollution-control measures should they be needed.

TECHNICAL DISCUSSION

Although little work has been done on the chemistry and mineralogy of trace elements in coal refuse materials, enough information is available on minerals and trace elements in coals to appreciate the possibilities for environmental degradation from this source. The character of the major minerals and rock types found in coals, coal-bearing strata and coal refuse materials is fairly well established.(4) In spite of some variation from locality to locality, and even within individual coal seams, certain classes of minerals are almost always present in coals. These minerals, listed in Table I, are the basic components of sedimentary and secondary rocks, and other inorganic matter, deposited adjacent to and within the coal beds.

The clay minerals are present in coals and coal refuse in greatest abundance. It is not unusual for 70% or more of the coal-associated inorganic matter to be of this type. An average of 52% clay in the mineral matter of 65 Illinois-Basin coals has been reported.(4) Quartz was found to represent about 15% and carbonates about 10%, while pyrites comprised about 25% of the total mineral content in these coals.

Many trace elements or minor minerals are present in coals and most should appear in the coal waste materials. In all, about 40 trace or minor elements have been identified in coals, and, undoubtedly others are present.(8) Except for a few elements, which are thought to be almost exclusively associated with the organic coal components, most of the trace elements in coals are distributed among the major mineral constituents.(4,9)

The relationships among selected trace elements and major minerals have been studied in over one-hundred Illinois coals.(10) This work suggests that most trace elements in coals reside within the structures of the major minerals as impurities or minor phases. As illustrated in Table II, a correlation was found between certain trace elements and specific mineral types. A consideration of this relationship between trace elements and minerals in coals, leads to the conclusion that trace elements in coal refuse materials are not likely to respond independently to weathering, leaching, burning or other chemical or physical processes, but more likely will be tied directly to the behavior of the major mineral components.

The important steps in the weathering and leaching of refuse banks or gob piles are relatively well understood.(2,3,11) In the presence of water and air, the pyrites present oxidize to produce soluble salts and sulfuric acid solutions.* This process requires both oxygen and water and is thought to be aided by certain bacteria. Oxidation occurs most rapidly at the exposed surfaces, and proceeds inward at a rate which depends on the permeability of the waste material to water and air. Overall, the pyrite oxidation process is exothermic, so reaction heat may become sufficiently high in the interior of the gob pile to ignite the waste materials. As the acidic solutions formed by pyrite oxidation drain through the wastes, they can dissolve or alter other mineral types, such as the carbonates and some of the clays.(12) A series of complex chemical equilibria eventually produces the highly mineralized, acidic waste waters characteristic of the runoff from coal mines and refuse dumps.

The fate of the trace elements in wastes subjected to weathering or burning is for the most part unknown. This gap in our understanding poses a number of questions regarding the behavior of trace elements in coal waste materials. What happens to the trace elements associated with the labile or soluble minerals during waste-dump weathering and burning? Do they distribute in solution in concentrations comparable to those in the solid phase, or do ion exchange or partitioning effects with other minerals or surrounding soils concentrate certain trace elements? What is the effect of pH and relative ionic strength on trace element behavior? And finally, what effects do the various processes used to control or treat drainage from waste disposal areas have on the trace-elements content of these solutions? These are important questions to be answered before the possible environmental effects of trace elements in coal refuse materials can be fully assessed or understood, and appropriate control measures can be developed.

PROGRAM OBJECTIVES

Recognizing the lack of information on which to properly assess potential environmental problems from trace elements in the vast quantities of coal cleaning wastes, EPA has begun to support research in this area. An EPA-funded program is now underway at ERDA's Los Alamos Scientific Laboratory, which is being conducted under an Interagency Agreement between EPA and ERDA. Funding for this program was begun in mid-1975. Current plans call for a 3-year project designed to accomplish the following primary objectives.

1. Identify the chemical forms, mineralogy and associations of trace elements in coal refuse materials and establish an understanding of the chemical properties and behavior of these materials.

2. Determine the fate of trace elements during the weathering and burning of coal wastes, and identify those elements or processes of possible environmental concern.

3. Establish chemical or physical methods for preventing or controlling environmental contamination from trace elements in coal refuse.

4. Investigate methods for economically removing or recovering useful trace minerals or metals from coal refuse materials.

PROGRAM DISCUSSION

To accomplish the proposed objectives, the project has been divided into three main tasks with 15 currently defined subtasks. Major milestones for the program have been established; these will be reviewed and revised as necessary.

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*The acid leaching of refuse materials is being described here, because it is a highly visible, worse-case example of the natural processes that can occur in these materials. Pyrites are present in most coal wastes, so the potential for acid build-up exists in most instances. The absence of pyritic material, insufficient moisture, low permeability, burning, high carbonate content, or other conditions can prevent the formation or spread of acids in gob dumps. It should not be concluded, however, that all is well if the water moving through the wastes is non-acidic. Available evidence shows that considerable dissolution and transport of mineral matter can also occur in these circumstances.(11)

Task I involves the planning and establishment of the directions that the technical investigations will take. This task covers the first 6 months of the program and is nearly completed. During this time, an extensive literature search on the chemistry and environmental behavior of trace elements in coal cleaning wastes was completed and a report and commentary on the literature, as it pertains to the present program, is being written. Methods and techniques for analyzing trace elements and minerals in coals and coal wastes were surveyed and those most applicable were chosen. Also, decisions were made concerning the coal waste materials with which to begin the laboratory studies.

Task II encompasses the laboratory activities to accomplish the first two program objectives. This task began concurrently with Task I, and will continue for at least the first 2 years of the program.

The early parts of this task, devoted to developing and standardizing methods for analyzing trace elements and minerals in coals and coal refuse, have been completed. Also, representative samples of both fresh and weathered coal cleaning refuse have been collected.

The intermediate stages involve the characterization of the trace elements and minerals of both fresh and weathered coal-waste samples, and preliminary identification of the trace elements of interest. Also, a trace elements balance on a "typical" commercial coal cleaning facility will be done to provide information about the distribution of these elements among the various products and waste streams.

The latter stages of task II involve studies of the chemical behavior of trace elements in coal wastes. The effects of weathering, leaching, oxidation and combustion on the trace elements in refuse materials will be investigated in the field and under simulated environmental conditions in the laboratory. Various computer-based models, designed to describe the behavior of minerals in aqueous solutions, will be used to help direct the laboratory studies. Other studies will include chemical agents or conditions not normally encountered in the environment. This work will lead to the development of new or modified methods for separating trace elements of interest from coal wastes.

In Task III, the information and technology generated in the earlier tasks will be used to develop means of removing or recovering trace elements of environmental or economic importance from coal cleaning wastes. Although the overall success of the program depends heavily on the success of this task, the specific programmatic steps that will be taken are difficult to define at this time. The removal or recovery schemes will, however, involve chemical or physical methods, or a combination of both, and are to be considered as new, modified or add-on steps to existing cleaning operations. Preliminary work in Task III is scheduled to begin in the latter half of the current fiscal year.

PROJECTION

This research program recognizes the greatly increased role that cleaned or processed coal will assume in the nation's energy picture, and reflects a growing public concern with trace element releases from fuel sources. The program is designed to provide a scientific assessment of potential environmental problems from trace elements in discarded coal processing wastes, and to lay the technological groundwork for assisting the coal industry in removing, recovering or preventing releases of environmentally harmful trace elements from coal refuse materials.

Initial research will provide necessary data and information about the character and behavior of refuse-borne trace elements under waste-pile conditions. Beyond this, it is difficult to comment on the course of the investigation. However, the latter parts of the program, involving the development of environmental control technology, are flexibly designed so emphasis can be rapidly concentrated in areas of need.

INTERAGENCY AGREEMENT AND RESOURCE ALLOCATION

This program is supported by pass-through funds from EPA to ERDA under Interagency Agreement No. IAG-D5-E681. The funding agency is the Industrial Environmental Research Laboratory of EPA at Research Triangle Park, North Carolina, and the performing agency is the ERDA Division of Environmental Control Technology, Washington, D.C. Technical work for the program is being conducted by ERDA's Los Alamos Scientific Laboratory at Los Alamos, New Mexico. Technical direction is provided jointly by EPA and ERDA.

This is one of two such programs provided initial funding in FY 76 by EPA. The other, a companion program on the environmental aspects of sulfur in coal processing wastes, is underway at Battelle, Columbus. Funding allocated to LASL by EPA for FY 76 and projected through FY 77 is as follows ($\$ \times 10^3$):

FY 76	FY 76A	FY 77	FY 78
300	*	*	†

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*Funding comparable to FY 76 anticipated per EPA guidelines.

†Not yet budgeted.

CONCLUSIONS

Concern about environmental contamination from trace elements in coal processing wastes is well justified. However, so little is known about the nature of these minor waste components, that it is difficult to adequately assess the magnitude or extent of trace element release from coal wastes. Nor is there a sufficient understanding of the chemistry or behavior of trace elements in coal refuse materials on which to base environmental control technology. The EPA/ERDA interagency research program at LASL is designed to address these problems from a fundamental basis and provide rapid and practical solutions.

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Table 1. - Major Minerals in Coals

Aluminosilicates	(Clay minerals)
Silica	(Quartz)
Carbonates	(Limestone, dolomite, siderite)
Sulfides	(Pyrite)

Table 2. - Trace Elements - Minerals Correlations

As, Be, Cu, Sb : Pyrite

B, Cd, Zn, Hg : Sphalerite

B, Cd, Mn, Se, Mo, V : Calcite

B, Cr, Mn, Cd, Mo, Se, V, Zn : Quartz

B, Cu, F, Hg, Sn, V : Clays

PHYSICAL AND CHEMICAL COAL CLEANING FOR POLLUTION CONTROL

James D. Kilgroe
Industrial Environmental Research Laboratory
Environmental Protection Agency
Research Triangle Park, North Carolina

INTRODUCTION

Coal constitutes the greatest energy resource now available to the U. S. It is estimated that coal reserves contain some 67 x 10^{15} BTU's,* enough to last 300 to 400 years under projected usage rates. However, all coals contain minor and trace elements which form pollutants during processing or combustion. Coal may be used as an environmentally acceptable energy source if suitable pollution control measures are taken.

Coal is primarily organic matter consisting of carbon, hydrogen, oxygen, nitrogen and sulfur. There are also trace amounts of other elements dispersed throughout the organic coal structure. Various amounts of mineral matter are also present, depending upon the characteristics of the individual coal and the method by which it was mined. The residual ash formed by the combustion of commercially used U. S. coals ranges between 3% and 20%, the average being about 14% by weight. Combustion of coal results in the formation of pollutants which include oxides of sulfur and nitrogen plus the elemental forms or compounds of beryllium, chlorine, fluorine, arsenic, selenium, cadmium, mercury, lead and other potential pollutants.

Sulfur dioxide (SO_2) is the pollutant of principal concern. Annual SO_2 emissions from coal combustion in 1974 were estimated to be 20.5 million tons. This represents 65% of the total SO_2 emissions for that year. On a national basis the 5.3 million tons of NO_x emissions from coal combustion represented 24% of the total 1974 NO_x emissions. Emissions of other potentially hazardous elements or compounds while not as large may present environmental or health problems because of their concentration in process waste streams, concentration in the environment or effects produced by prolonged exposure at low concentrations.

The applicability of coal desulfurization to sulfur dioxide emission control is dependent upon emission regulations which must be met. Only 14% of the 455 U. S. coals tested for physical cleanability by the Bureau of Mines are capable of meeting federal new source performance standards (NSPS) for steam generators (1.2 lb SO_2,10^6 BTU).(1) It has been estimated that if physically cleaned to a 90% BTU recovery and a 1-1/2 in. top size 24% could meet NSPS. Physically cleaned to the same BTU recovery and top size, 35% are capable of meeting standards of 2.0 lb $SO_2/10^6$ BTU while over 60% are capable of meeting a standard of 4.0 lb $SO_2/10^6$ BTU (see figure 1). Many states have emission standards as high as 4.0 lb $SO_2/10^6$ BTU. Thus there may be a significant application of physical coal cleaning to meeting state emission regulations.

Chemical coal cleaning is capable of higher levels of desulfurization. Thus it potentially has a wider range of applicability. In some instances, depending upon the coal, the emission regulation and site specific considerations, it may be the most cost effective method for SO_2 emission control. However, for other cases chemical coal cleaning may not be competitive with either physical cleaning or flue gas desulfurization. Figure 2 presents the ranges of estimated costs and the degree of applicability for different sulfur emission control strategies.

TECHNICAL DISCUSSION

Although nitrogen and other elements are of concern as pollutants, the primary emphasis in EPA's programs has been the development of technology to remove sulfur. The total sulfur content of American coals varies from less than 1% to more than 6%. It is present in coal in several forms. In the organic form it is chemically bonded to the carbon atoms and cannot be removed by physical methods. In American coals it generally represents from 20 to 85% of the total sulfur present. The inorganic form is present mainly as the chemical species ferrous disulfide (FeS_2), either in the form of pyrite or its polymorph marcasite. In coals from different coal regions of the U. S. there is a large variability in total sulfur content and in the ratio of organic to inorganic sulfur. To a lesser extent this rule of variability holds for coals from the same region and even for coal from the same mine. The specific properties of each coal will determine its amenability to sulfur removal by physical or chemical methods. Thus processes for sulfur removal must be based upon the chemical and physical properties of the coal to be used in the process. No process is universally applicable to all coals.

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*It is EPA policy to report measurements in the international system of metric units. For clarity of presentation, units used in this paper will be those commonly used for engineering activities in the U.S. Conversion factors are presented at the end of the paper.

Figure 3 presents estimates of the sulfur levels which can be attained by various levels of physical and chemical coal cleaning. A principal objective of EPA's coal cleaning program is to identify and support development of various processes capable of being used to meet SO_2 emission standards in a commercially competitive manner. Corollary objectives are the characterization of all pollutants from these processes and the development of appropriate pollution control technologies.

Physical Coal Cleaning

Physical coal cleaning to remove mineral matter and mining residue has been carried out for the past several decades using many physical separation techniques singly or in combination. Techniques now widely used on a commercial basis for the removal of these impurities include jigging, heavy media separation, tabling, and flotation. These methods depend upon differences in physical properties of the coal and impurities to achieve separation. Since 1965 EPA, the Bureau of Mines, the Bituminous Coal Research, Inc., and others have cooperatively evaluated these and other techniques for the selective removal of pyrite from coal(2). Some of the "other" techniques evaluated have included thermal-magnetic separation, immiscible liquid separation, selective flocculation, electrokinetic separation and two-stage froth flotation. Techniques which rely upon differences in specific gravities of the coal and pyrite particles have been found to be the most commercially viable for desulfurization. Froth flotation which depends upon the surface properties of the particles has also been found to be a useful commercial technique.

Since some coals are more amenable than others to sulfur removal by physical methods, studies have been performed on over 455 U. S. coals to determine pyrite liberation by size reduction and separation by specific gravity differentials. The 455 samples tested are from mines which provide more than 70% of the coal used in U. S. utility boilers. The laboratory float-sink tests performed in media of specific gravities ranging from 1.3 to 1.9 and size fractions from a minus 1-1/2 inches to a minus 14 mesh, provide information on the pyritic sulfur which can be removed from these coals.(1,3)

The results of these float-sink or cleanability studies indicate that the pyritic sulfur removal increases with reduced coal particle sizes and specific gravities. Crushing to finer sizes liberates more of the dense mineral matter from the coal matrix and low media specific gravities allow more of this dense material to sink. At low specific gravities a cleaner product is obtained; i.e., ash and pyritic sulfur are decreased. However, this clean product is obtained at the expense of increased BTU losses. Theoretically at very fine sizes a large percentage of the pyritic sulfur could be released from the coal matrix and separated without excessive BTU losses. This fact is extremely important. It implies that to enhance sulfur removal more of the coal must be crushed and processed at finer sizes than historically practiced in coal preparation. This will require modifications to current processing plant design practices. These design changes will necessarily incorporate techniques for improved fine coal separation, dewatering and drying. Modified pollution control and waste disposal techniques will also be required.

Table 1 presents data on the amounts of pyritic sulfur which can be removed from coal samples from six regions by crushing to a top size of 3/8 in. and by separation at a specific gravity of 1.6. It is important to note that the pollutant potentials of the cleaned coals represented by the data in column 5 are significantly different. (The term "pollutant potential" is used since it is assumed that all the sulfur contained in the cleaned coal is converted and emitted as SO_2.) For example the average SO_2 pollutant potential for the Northern Appalachian, the Southern Appalachian and the Eastern Midwest coal region samples are 2.7, 1.3, and 4.2 lb $SO_2/10^6$ BTU, respectively.

In addition to the large regional variability in the amount of pyritic sulfur which can be removed, there is also a variation in the coal cleanability within a given region and even within a specific mine. This variability in coal cleanability in a given mine is graphically illustrated by the data presented in figure 4.

Other studies supported by EPA have evaluated the effectiveness of commercial equipment for the removal of pyritic sulfur.(2) Physical coal cleaning development needs identified from these studies include:

1. The continued evaluation of the sulfur reduction potential of U.S. coals by gravimetric separation.
2. The evaluation and characterization of commercial coal preparation equipment in separating pyritic sulfur from fine coal.
3. The development of equipment to monitor and control the performance (sulfur removal and BTU recovery) of coal preparation processes.

4. The evaluation and development of improved fine coal recovery and dewatering techniques.
5. The characterization of air pollution emissions and waste water effluents and the development of improved pollution control methods.
6. The evaluation and development of improved fine coal residue disposal techniques.
7. An evaluation of the effects of physically cleaned coal on boiler performance (primarily with respect to tube fouling) and stack particulate control device performance.
8. The demonstration of the above in commercially operating coal preparation plants and coal firing boilers.

Chemical Coal Cleaning

Chemical cleaning of coal, to selectively remove pollutant-forming constituents while maintaining the structural integrity of the coal matrix, is a technological approach to pollution control which is receiving increasing emphasis for research and development. Unlike physical coal cleaning, chemical cleaning is not now used in coal preparation processes. However, chemical coal cleaning, if successfully developed, possesses the potential for removing both organic and inorganic sulfur from coal.

In chemical desulfurization processes, finely ground coal is treated with a reagent under specific pressure and temperature conditions. The amount of pyritic and organic sulfur removed from the coal structure is dependent upon the coal particle size, the coal physical and chemical properties, the reagent, the pressure, the temperature and time of reaction.

Early work supported by EPA demonstrated the effectiveness of leaching for removing pyritic sulfur from a variety of coals, including those not amenable to physical desulfurization. Other studies identified specific U. S. coals amenable to desulfurization by pyrite leaching and evaluated processes capable of leaching organic sulfur.

Development work needed in the chemical desulfurization of coal includes the performance of additional bench and pilot scale work to define the appropriate combinations of reactants, pressure, and temperature for optimum sulfur removal. Once these variables have been established for each of the candidate processes then continuous pilot and demonstration scale process studies must be performed. Pollutant emission characteristics and the pollution control methods needed for each of these processes must also be evaluated.

PROGRAM DISCUSSION

EPA's coal cleaning program activities are concentrated in six major areas as shown in Table 2 and discussed below.

General Support

Work under this area may encompass a wide range of activities from aid in arranging symposiums to the performance of test and evaluation work needed in support of other programs being conducted for EPA. Most generally this work is provided under service contracts, basic ordering agreements or major level of effort contracts.

Input Material Characterization

A major activity has been the identification of pollution forming elements in U. S. coals. Previous work in this area has been supported by EPA and the U. S. Bureau of Mines. The U. S. Geological Survey and ERDA are now actively engaged in setting up a comprehensive computerized inventory listing of the elemental compositions of U. S. coals. The Bureau of Mines, supported in part by EPA funds, is continuing to characterize the sulfur and ash release potentials of U. S. coals under gravimetric separation conditions (float-sink tests).

Environmental Source Assessment

A single 3-year, 60,000 man-hour level of effort contract will be used to assess the environmental impact of coal handling, coal transportation, physical coal cleaning processes and chemical coal cleaning processes. Under this contract, tests will be performed to characterize the multi-media pollutant emissions from those various unit operations associated with the production of a cleaned coal. The best current pollution control technology will be identified, as will the need for the development of improved control technologies. Trade-off studies will be performed to determine the most cost effective and least environmentally damaging mixes of pollution control techniques. These trade-off studies will necessarily encompass a comparison of various clean fuel strategies; i.e., a comparison of physical coal cleaning, chemical coal cleaning, flue gas desulfurization, or combinations thereof. Proposals for performance of this contract have been received and are under evaluation.

Control Technology Development

Development of technology for pollution abatement and control will be performed under EPA contracts and under an interagency agreement with the Bureau of Mines. Work directed by the Bureau of Mines will include research on: surfactants to improve the performance of vacuum filters, the control of processing plant black water, surface phenomena in coal dewatering and adsorption/desorption reactions in coal pyrite flotation. Work to be performed under EPA contract will initially be limited to an assessment of control technology development needs. Technology development activities will be initiated as development needs are identified.

Physical Coal Cleaning Development

Physical coal cleaning technology for sulfur removal is also being developed jointly by EPA and the Bureau of Mines. The Bureau's work is supported both by funds from EPA and the Department of the Interior. Work planned or in progress at the Bureau of Mines or contracted by the Bureau of Mines with EPA funds includes:

1. Design, construction and operation of a coal cleaning test facility.
2. Demonstration of two-stage froth-flotation circuitry in a commercially operating plant.
3. Development of a coal cleaning plant computer simulator model.
4. Research on improved magnetite recovery from fine coal.
5. An evaluation of instrumentation needed for monitoring and precise control of preparation plant clean coal products.
6. Development of equipment for the magnetic separation of pyrite from coal.
7. Development of an improved circuit for media density control.
8. Evaluation of a coal waste stabilization agent.
9. Commercial evaluation of a technique for agglomeration and dewatering of coal preparation wastes.

Work supported by EPA will be primarily conducted under a large 3-year contract to assess and develop coal cleaning technology. Major work tasks under this contract (proposals are now being evaluated) will also include activities in support of chemical coal cleaning development. Activities under this contract will include:

1. Experimental work to assess the degree to which pyritic sulfur is separated from coal in commercial coal cleaning plants.
2. An evaluation of fine coal dewatering and handling techniques.
3. An evaluation of coal preparation requirements for synthetic fuel conversion processes.
4. Economic and bench-scale evaluations of selected chemical coal cleaning processes.
5. The evaluation and development of pollution control techniques for coal preparation processes.
6. An evaluation of the effects of coal cleaning on the performance of user system (boilers, electrostatic precipitators, etc.).
7. The performance of cost and pollution trade-off studies on coal preparation equipment and processes.

In addition to the above activities, EPA and the Bureau of Mines are considering support of a demonstration of physical coal cleaning in meeting federal and state emission standards. The General Public Utilities Corp. (GPU) is planning to use physical coal cleaning for this purpose at the Pennsylvania Electric Company (PENELEC) Homer City Plant. Their emission control strategy, called the multi-stream coal cleaning strategy (MCCS), will use two streams of physically cleaned coal from a single processing plant. One cleaned coal stream will be used to meet Pennsylvania emission standards of 4.0 lb $SO_2/10^6$ BTU in two existing boilers. The other coal stream will be used to meet federal New Source Performance Standards (1.2 lb $SO_2/10^6$ BTU) in a boiler now under construction. Bureau of Mines support for this program will probably include development work on portions of the fine coal cleaning circuit and technical consultation on the design, operation and testing of the demonstration plant. EPA will probably support the test and evaluation activities at the demonstration plant.

Chemical Coal Cleaning Development

Chemical coal cleaning development activities currently supported by EPA include: the design, construction and operation of a pilot plant test facility to evaluate the chemical leaching of pyrite from coal; and bench scale work to evaluate other chemical desulfurization processes.

The IERL-RTP program in chemical coal cleaning was initiated early in 1970 with a screening study at TRW of chemicals for sulfur and nitrogen removal from coal. This initial study led to the identification of a process possessing considerable merit for the near-total removal of inorganic sulfur from coal. A consistently high level of inorganic sulfur removal was achieved regardless of the variations in the coal being evaluated. This process has continued to evolve under EPA support until, at the present time, work is underway at TRW on the construction of a 250 pound per hour experimental test facility. Termed the Meyers Process, initial shakedown and operation of this facility should be realized early in 1977. In support of test unit program a broad program of basic experimentation will be conducted to evaluate the commercial applicability of the process.

During the early (1972-73) period of work on the Meyers Process consideration was given to other chemical coal cleaning projects which were underway. The U. S. Bureau of Mines was studying the cleanability of coal using aqueous caustic solutions, but the early results showed no greater potential for sulfur removal than that achievable by the Meyers Process. The Institute of Gas Technology (IGT) was examining the potential for coal hydrotreatment at low pressures in the presence of an acceptor material for the selective removal of organic and inorganic sulfur from coal. As a result of the IGT work, a program was initiated by EPA to study the potential of this process in the removal of organic sulfur from coal. The viability of the reaction system was confirmed and a modified experimental program has been initiated to establish overall process requirements.

Within the past two years a number of other concepts for chemical cleaning of coal have been reported. Discussions have been held with a number of organizations who are experimentally evaluating chemical coal cleaning. As a result of discussions with Battelle, an EPA program has been initiated to study the Battelle Hydrothermal Process for the removal of organic and inorganic pollutants from coal. Under this program experiments are being conducted to define the combustion products from the feed and cleaned coal. The primary objective of the study is to determine the operating conditions which maximize pollutant removal from the product coal. Additional tests will be performed to characterize the spent leachant, to define disposal requirements and to evaluate possible by-product uses for process residuals.

Programs on two other processes to study both inorganic and organic constituent removal through novel concepts for wet and for dry coal cleaning are also being evaluated. It is expected that comprehensive feasibility test programs will be performed to establish the overall technical merits of these two systems.

Several other chemical coal cleaning methods are being evaluated by EPA for possible support, and open advertisement for additional chemical coal cleaning technology development work is being considered.

Projection

The relatively low costs of physical and chemical coal cleaning processes will make these pollution abatement techniques increasingly attractive in future years. Coals which are amenable to physical cleaning for pyritic sulfur removal will be identified and used in preference to other coal sources. In some instances a combination of physical coal cleaning and flue gas desulfurization will be used as the most economical method of sulfur emission control. Although physical coal preparation is now widely used for ash and mining waste removal, the use of this technology for sulfur removal will probably not be widely used until 1985 or 1990. The major development focus for physical coal cleaning will be in the areas of:

1. Improved techniques for separation of fine coal and pyrite.
2. Improved process control to ensure that the product coal meets sulfur, ash and BTU specifications.
3. Improved techniques for dewatering and handling of coal fines.
4. Improved pollution control and waste disposal methods.

Chemical coal cleaning has a wider area of application than physical coal cleaning, as a greater fraction of the total sulfur can be removed. Cost estimations indicate that chemical cleaning should be cost competitive with flue gas desulfurization and the new synthetic fuel conversion processes. However, additional chemical coal cleaning technology development is needed before this method of sulfur emission control is widely used.

RESOURCE ALLOCATION

From FY 65 to FY 73, EPA and its predecessor organizations allocated over $6 million to research and development of coal cleaning programs. Since FY 74 the availability of new resources for energy related research has enabled EPA and the Bureau of Mines to support the research, development and demonstration programs which are needed to accelerate the commercialization of coal cleaning processes for the control of pollution from coal combustion. Funds allocated by EPA for coal cleaning since FY 74 are as follows:

	($1,000)		
	FY74	FY75	FY76*
EPA Direct	1076	3430	2470
Interagency Agreement (Bureau of Mines & ERDA)	200	900	1080
Total	1276	4330	3550

*Projected Budget

CONCLUSIONS

Previous programs to develop physical and chemical coal cleaning as techniques for pollution control have:

- Provided a preliminary data base on the physical cleaning potential of U.S. coals.
- Demonstrated that technology commercially used for the removal of inert matter from coal can be used for the removal of pyritic sulfur.
- Demonstrated at bench scale the effectiveness of leaching as a means of removing pyrite from a variety of coals, including those not amenable to physical desulfurization.
- Identified specific coals amenable to desulfurization by pyrite leaching.
- Estimated the costs and environmental benefits of physical and chemical coal cleaning process for pollution control measures.

Current and future development activities will focus on:

1. The assessment of environmental impacts of physical and chemical coal cleaning processes.
2. Development and demonstration of improved coal cleaning techniques.
3. Development and demonstration of improved pollution control techniques.

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CONVERSION FACTORS

1 lb = 0.4536 kg
1 ft = 0.3048 m
1 BTU = 1054.88 J
1 ton = 0.9072 metric ton
1 BTU/lb = 2326 J/kg

Figure 1. Percent of 455 United States coal samples meeting the current EPA new source performance standard for steam generators (Ref. 1).

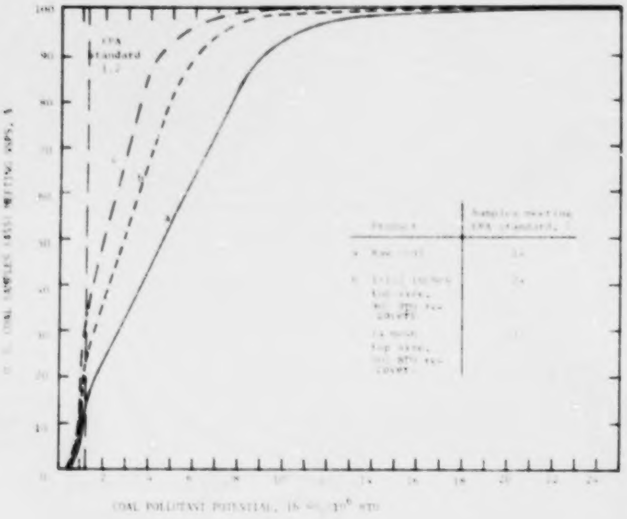


Figure 2. Cost of sulfur control.

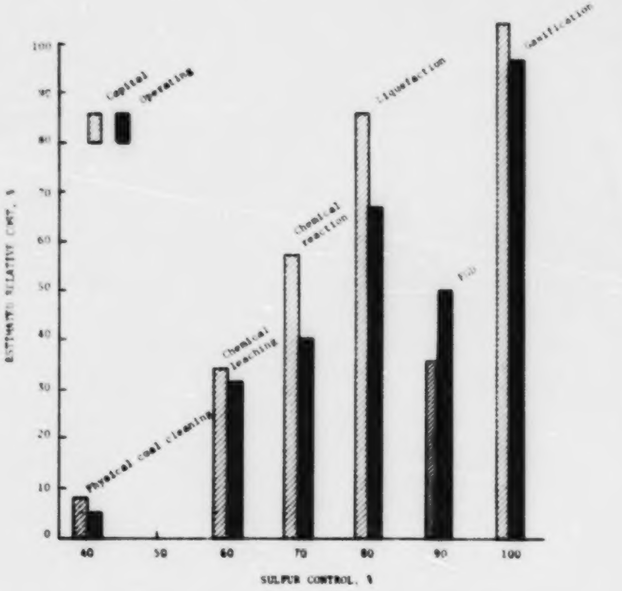
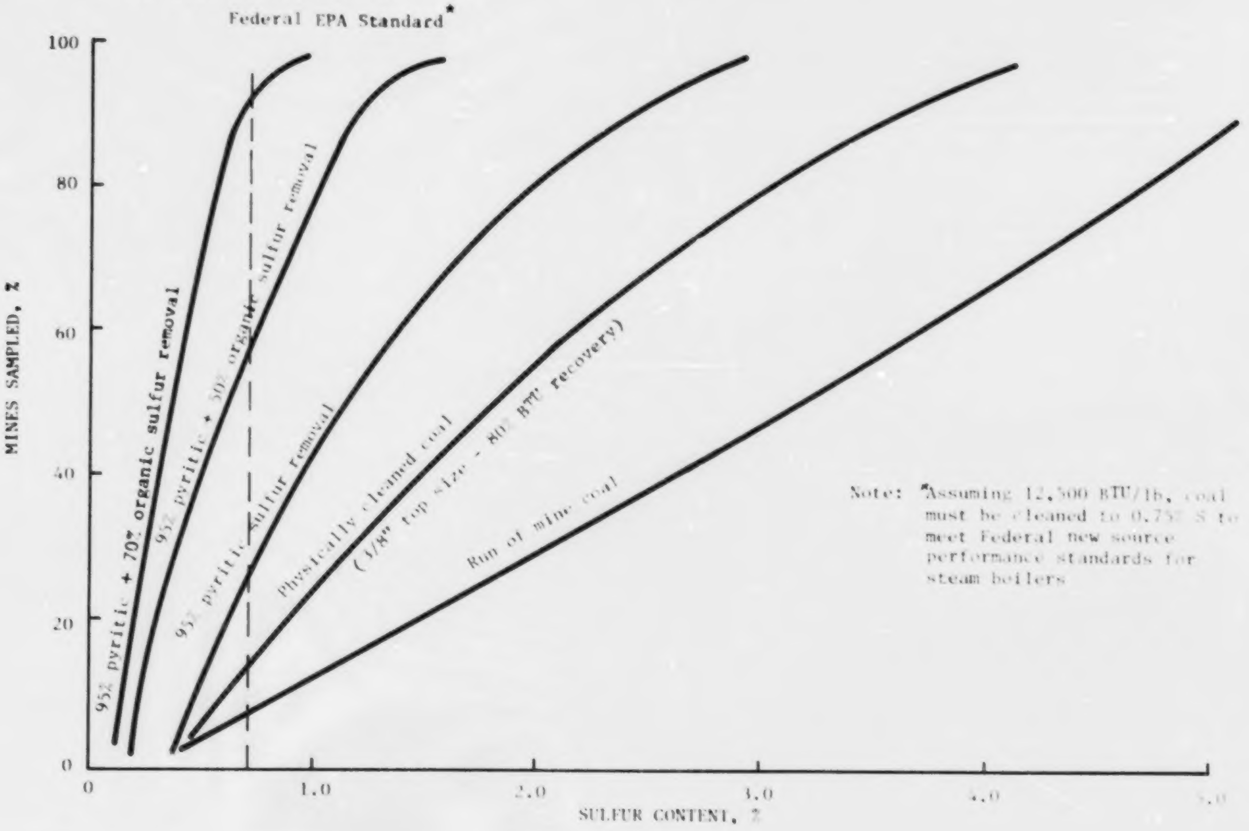


Figure 3. Potential levels of desulfurization for U.S. utility coals.



Note: *Assuming 12,500 BTU/lb, coal must be cleaned to 0.75% S to meet Federal new source performance standards for steam boilers

Figure 4. Variations in total sulfur, sulfur forms, and pyrite removed by physical cleaning of face samples, Pittsburgh seam coal from a single mine in Greene County, Pennsylvania (ref. 4).

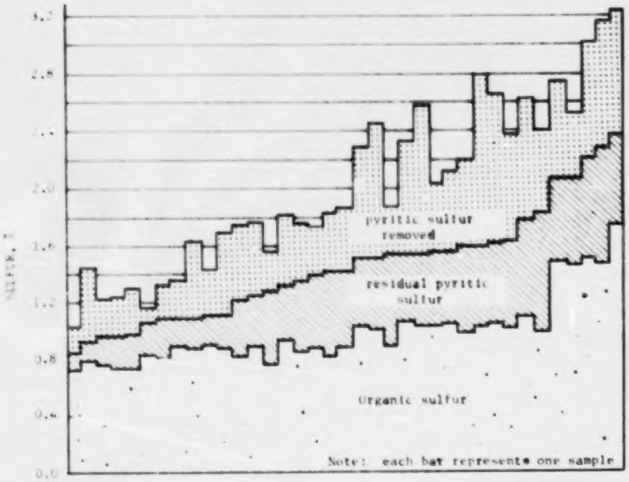


Table 1. Summary of the Physical Desulfurization Potential of Coals by Region (1) (a)

Cumulative analyses of float 1.60 product

Region	No. Samples	Percent: BTU recovery	Percent: Ash	Percent: Pyritic sulfur	Percent: Total sulfur	Pounds $SO_2/10^6$ BTU (b)	Calorific content, BTU per pound (c)	SO_2 removal efficiency required for NSPS (d) percent
Northern Appalachian	227	[illegible]	8.0	0.85	1.88	2.7	13,766	56
Southern Appalachian	35	96.1	5.1	0.19	0.91	1.3	14,197	8
Alabama	[illegible]	90.4	5.8	0.49	1.16	1.7	14,264	29
Eastern Midwest	95	94.9	7.6	[illegible]	2.74	4.2	13,138	71
Western Midwest	44	91.7	8.3	1.80	3.59	5.4	13,209	78
Western	44	97.6	6.3	0.10	0.56	0.9	12,779	None
Total U.S.	455	93.8	7.5	0.85	2.00	3.0	13,530	60

(a) Summary of the composite product analyses for 3/8 inch top size, float-sink tested at 1.6 specific gravity.

(b) Based upon the moisture free BTU value of the float coal and assuming all sulfur is converted to SO_2. Actual emissions will vary depending on the as-fired coal moisture content and the conversion efficiency of sulfur to SO_2.

(c) Moisture free basis.

(d) Values may require adjustment to account for the as-fired coal moisture content and efficiency of sulfur conversion to SO_2. NSPS = Federal New Source Performance Standards for Steam Generators (1.2 lb $SO_2/10^6$ BTU).

Table 2. Summary of Physical and Chemical Coal Cleaning Program

General Support

- **Dissemination of information - manuals and reports**
- **Program Support**

Input Material Characterization

- **Sulfur and ash release potential (washabilities)**
- **Characterization of coal and residues for trace elements and mineral matter**
- **Contaminant removal techniques**

Environmental Source Assessment

- Physical and chemical coal cleaning
  - Multi-media discharges from existing and new techniques or methods
  - Applicability of existing control technology
  - Identification of needed new or modified controls

Control Technology Development

- Development/assist in development of control techniques
- Dewatering of coal and black water control
- Coal refuse pond elimination

Physical Coal Cleaning Development

- Development and demonstration of two-stage froth-flotation techniques
- Assist in design and construction of a coal cleaning pilot plant
- Development of a physical coal cleaning computer model
- Demonstration of the use of physical coal cleaning to meet emission standards

Chemical Coal Cleaning Development

- Design, construction and operation of a test reactor for chemical leaching of pyrite
- Evaluation of chemical cleaning technology concepts

COAL PREPARATION

Albert W. Deurbrouck
U. S. Department of the Interior
Bureau of Mines
Coal Preparation and Analysis Group
Pittsburgh, Pennsylvania

INTRODUCTION

Coal Preparation is a proven technology for upgrading raw coal by physical removal of associated impurities. The physical upgrading of metallurgical grade coal has long been considered a necessity; however, the full potential of coal preparation as a means to upgrade steam coals has yet to be realized. Large reserves of low- to intermediate-sulfur content coals can be upgraded by physical means to meet the new source SO_2 emission standards established by EPA.

Current emphasis in coal preparation research is principally directed at upgrading fine size coal, particularly removing pyrite. Continuing coal washability studies clearly show the significant sulfur reduction potential of stage-crushing and specific gravity separations. Much work is underway to maximize usable coal recovery.

Sulfur in coal occurs in three forms: organic, sulfate, and pyritic. Organic sulfur is an integral part of the coal matrix and, generally, cannot be removed by direct physical separation. It comprises from 30 to 70 percent of the total sulfur in most coals. The sulfate-sulfur content is normally an oxidation product which is water soluble and therefore readily removed during coal cleaning. Sulfate-sulfur contents in coals are generally less than 0.05 percent. Pyritic sulfur occurs in coal as discrete, although sometimes microscopic-sized, particles. It is a heavy mineral with a specific gravity of about 5.0. In many U. S. coals, the pyritic sulfur is approximately 60 to 70 percent of the total sulfur content of the coal. Such coals are obvious candidates for significant upgrading by conventional coal beneficiation techniques.

COAL WASHABILITY

All coal cleaning methods in general use, except froth flotation, rely upon specific gravity separation. Consequently, the specific gravities of the impurities associated with coal are of primary importance. Other factors being equal, the heavier impurities can be removed in the cleaning operation more easily than can the lighter impurities, which approach in density the coal from which they are to be separated. To determine the preparation methods and the equipment needed to clean coal, information is needed on size and specific gravity distribution of the raw coal; moisture, ash, and sulfur contents; heating values (Btu content); and ash fusibility. Washability studies are being conducted to determine the quantity and quality of coal that can be produced at a given specific gravity of separation.

A washability study of a coal is made by testing the coal sample at preselected, carefully controlled specific gravities. This is commonly termed "float-sink" analysis and/or specific gravity fractionation. The specific gravity fractions are dried, weighed, and analyzed for ash and sulfur content. These data are mathematically combined on a weighted basis and used to develop the "washability curves" that are characteristic of the coal.

A study was initiated in 1965 to determine the sulfur release potential of coals from principal utility coal producing coalbeds of the U. S. This study, initially funded by the National Air Pollution Control Administration, is currently being funded by the Environmental Protection Agency (EPA).

To date, a total of 455 samples have been evaluated. All of the samples were collected from working mines producing steam coals; where possible, the largest mines from a specific bed were sampled.

Washability analyses performed on these samples show the effect of crushing on the liberation of pyritic sulfur and other impurities.

The 455 raw coal samples contained an average of 14.0 percent ash, 1.91 percent pyritic sulfur, 3.02 percent total sulfur, and 12,574 Btu per pound. This is equivalent to 4.8 pounds SO_2/M Btu fired at the powerplant. For a coal to meet the current new source sulfur emission standard of 1.2 pounds of SO_2/M Btu, a coal of 12,500 Btu per pound having a sulfur content of 0.75 percent or less would be required. Clearly, a formidable sulfur problem exists in U. S. coals. However, 63 percent of the sulfur in these coals was pyritic, so significant sulfur reductions by physical coal cleaning is possible.

The ash, pyritic sulfur, total sulfur, and heating value contents varied considerably as would be expected when washability data of coals from various regions of the U. S. are evaluated.

The coals in the eastern U. S. ranged in rank from low- to high-volatile bituminous. The low-volatile coals found in the southern part of this area contained, on the average, 1.0 percent total sulfur and 13,314 Btu per pound. Generally, they could be upgraded after crushing and gravimetric separation to meet the new source sulfur emission standard.

The high-volatile coals found in the northern part of this area contained, on the average, 2.01 percent pyritic sulfur, and 3.01 percent total sulfur. Crushing these coals to 14 mesh top size and removing the sink 1.40 specific gravity material would provide an average product analyzing 0.43 percent pyritic sulfur and 1.46 percent total sulfur. Thus, physical coal cleaning could provide reductions in pyritic sulfur of 76 percent and total sulfur of 46 percent.

The coals of the midwest U. S. were, on the average, high sulfur content coals analyzing 2.70 percent pyritic sulfur and 4.34 percent total sulfur. Because of the high average organic sulfur content of 1.63 percent, these coals generally could not be upgraded to meet the new source sulfur emission standard. However, crushing these coals to 14 mesh top size and removing the sink 1.40 specific gravity material, reduced average pyritic sulfur by 68 percent and average total sulfur by 37 percent.

The coals of the western U. S. are generally of low sulfur content as mined, averaging 0.68 percent total sulfur; however, these coals contain up to 40 percent inherent moisture, and, consequently, they are low-Btu content coals that barely meet, on the average, the 1.2 pounds of SO_2/M Btu new source emission standard.

FROTH FLOTATION

The program for development of fine coal cleaning techniques to remove sulfur has resulted in the development of a two-stage pyrite flotation process. Early experimental work showed that the quantity of pyrite reporting with the clean coal float product increased with increasing additions of the frothing agent. In addition, several polyvalent metal salts such as ferric chloride, aluminum chloride, chromium chloride, and cupric sulfate were found to be pyrite depressants. Apparently, these positively charged ions are adsorbed on the pyrite surface. This hypothesis was supported by zeta potential determinations which showed that suspended coal and pyrite particles in solutions containing metal salts are positively charged in the pH range where depression occurs.

Effective sulfur reductions with high coal recovery were also achieved by two-stage rougher-cleaner flotation in which the clean coal froth concentrate from the first stage was refloated. In all of this earlier work, it was recognized that a portion of the pyrite reported to the clean coal froth product because it was either too fine a size and became mechanically entrapped in the froth, or it was attached to floatable coal. To combat this problem, a unique froth flotation process was developed and patented by the Bureau to remove pyritic sulfur from fine size coal. The process consists of a first-stage standard coal flotation in which high ash refuse and the coarse- or shale-associated pyritic sulfur are removed as tailings. The first stage coal froth concentrate is then repulped in fresh water, the pH is maintained below 7, and a pyrite collector and a frother are added to float any pyritic material carried over with the first stage froth. A coal depressant is also added, and the second stage underflow is collected as the final clean coal product.

Laboratory and pilot plant flotation tests with coals from various coalbeds throughout the eastern U. S. showed that pyritic sulfur reductions of up to 90 percent could be achieved using this technique.

MISCELLANEOUS CLEANING

The commonly used fine coal cleaning devices such as tables, dense medium cyclones, hydrocyclones, and jigs which have application for pyritic sulfur reduction have been well developed. It is quite possible that only small technological advances can be made in the separating performance of these units at disproportionately high research and development cost. There would appear to be little need for such work at this time. However, there is no viable technique for dry removal of pyritic sulfur from coal. This represents an area of obvious need and much interest today.

A number of wet and dry magnetic separation techniques have been advanced in the past but to date have been found lacking. Early work in conversion of pyrite to a magnetic mineral pyrrhotite proved to be quite expensive and difficult to implement. Work on high field gradient magnetic separators is now being undertaken, and a technique has been developed by which the admixture of a dry chemical to the coal enhances the magnetic susceptibility of the pyrite and other coal associated impurities. These are interesting approaches which may prove quite fruitful.

CHEMICAL COAL PREPARATION

For coal preparation to be a totally viable process in the long range picture, however, some removal of organic sulfur must be obtained. To this end, considerable interest is now being generated in the development of a chemical process for removal of organic sulfur from the coal molecule without the destruction of the physical characteristics of the coal particle. Organic chemists have shown, on a laboratory scale, the theoretical possibility of such a technique.

Several chemical methods for sulfur removal have been developed and investigated at the Pittsburgh Energy Research Center. The one which currently shows the most practicality requires only the simplest of reagents, air and water. Heating coal with compressed air (400 to 1,000 psi) and water to between 150° C. and 200° C. at residence times from 5 minutes to 1 hour converts all the pyritic sulfur as well as up to 45 percent of the organic sulfur to aqueous sulfate (most of it appears as sulfuric acid). This extensive sulfur removal would make a large amount of eastern and midwestern coal environmentally acceptable for boiler fuel.

A dozen representative coals, spread geographically from Pennsylvania to Iowa, have been investigated for ease of sulfur removal using a standard set of reaction conditions in a stirred batch autoclave system. Under 800 psi initial pressure of air, over 90 percent of the pyritic sulfur has been removed from each of these coals at 150° C. In the case of coals which are naturally low in organic sulfur content but high in pyritic sulfur, this simple treatment is sufficient to make them suitable for use as fuel. At somewhat higher temperatures, 180° C. to 200° C., a portion of the organic sulfur is also oxidized to water-soluble sulfate. In the case of an Indiana No. 5 bed coal, 45 percent of the organic sulfur, as well as practically all of the pyritic sulfur, was removed as aqueous sulfate after treatment with compressed air and water at 200° C. An Indiana coal from Spencer County, containing 5.8 percent sulfur, lost 83 percent of its total sulfur yielding a product with less than 1 percent sulfur.

Total energy efficiency of the process is high. Only about 3 to 7 percent of the Btu value of the coal is lost due to addition of oxygen. Since this oxidation reaction is exothermic, most of this energy can be recovered as heat used within the process. Recoverable fuel value for this process should be near 90 percent. Much lower values have been reported for alternative methods of providing low sulfur fuels from coal.

LIGNITE UPGRADING

The lignite coal deposits of Montana and North Dakota represent one of the largest relatively untapped fossil fuel reserves in the U. S. totalling more than 220,000 million tons of recoverable low sulfur content reserves. Most of these reserves can be easily and inexpensively mined as the relatively thick coalbeds lie close to the surface. However, lignite utilization has been limited because of the material's high inherent moisture content, tendency to spontaneously combust, and often high sodium content. The average Montana-North Dakota lignite contains about 40 percent moisture, 6,700 Btu/lb, and up to 1.2 percent sodium.

A research program is now underway at the Bureau of Mines to upgrade this coal to a product containing less than 10 percent moisture, about 10,000 Btu/lb, and 0.3 percent sodium. At this time, we envision the final product as a pellet of sufficient mechanical strength to resist breakage during shipment and storage. Further, a well compacted pellet will be resistant to spontaneous combustion. This research project is basically a novel application of known technologies. The raw lignite, crushed to about 1/8 inch top size, will go to an ion exchange vessel where its inherent sodium content will be reduced to acceptable levels. The material will then be agglomerated into pellets of about 1/4 inch diameter. The pellets will be heat-dried to contain 5 to 10 percent total moisture.

FINE COAL DEWATERING

The most persistent and vexing problem associated with coal processing is the dewatering and drying of the clean coal and reject products. Fine coal handled or cleaned in slurry form in coal preparation plants is dewatered to render it suitable for conveying and blending, to decrease its transportation cost, and increase its effective calorific value. Fine refuse dewatering is especially difficult and poses some serious environmental problems. Removal of water from coal represents a significant portion of the overall cost of coal washing. Research is being carried out on the dewatering of fine size coal and refuse with emphasis on improving mechanical dewatering processes and minimizing the need for thermal drying. Vacuum filtration research in the laboratory has shown that fine size coal can be dewatered effectively by washing the filter cake with hot water containing hydrocarbon-type surfactants during the normal air drying cycle. It was found that the moisture content of filtered coal can be reduced to about 10 percent. If this technique can be commercially applied, the need for thermal driers would be greatly reduced.

In the western states where water is often scarce and the principal coal associated impurity is high ash rock, pneumatic coal cleaning processes should have application. At least one new device is now available, the FMC dry separator. This is a vibrating inclined table that appears to make an acceptable separation.

Coal preparation, an old friend, could well become one of the glamorous new technologies to emerge as a result of the energy crisis.

ENVIRONMENTAL CONTROL FOR OIL SHALE PROCESSING

Thomas J. Powers
U. S. Environmental Protection Agency
Industrial Environmental Research Laboratory
Cincinnati, Ohio

INTRODUCTION

A significant source of potentially available energy in the United States is oil shale. The vast oil shale deposits are estimated to contain 2,200 billion barrels of oil, primarily throughout the Green River Formation in Colorado, Utah, and Wyoming. It is estimated that one ton of this oil shale can produce more than 25 gallons of oil. Lower quality oil shale is located throughout the United States which could provide over 40,000 billion barrels of oil if adequate extraction techniques could be developed. As we develop this resource, it will be necessary to protect the environment through application of adequate control technologies for the mining and processing of oil shale. Because of the magnitude of these processing activities and potential for environmental damage, the EPA has undertaken programs that will lead to the identification, development and/or demonstration of cost-effective pollution control technology. The urgency of oil shale process development necessitates a rapid response in environmental protection methodology.

The overall strategy for oil shale environmental R&D by the Environmental Protection Agency relates to six major activities: exploration, mining, shale preparation, processing, land reclamation, and product transportation. EPA's R&D efforts for controlling emissions, effluents and solid waste residues include environmental impact analyses, pollutant characterization, available control technology evaluations, and development and demonstration of new pollution control techniques.

OIL SHALE PROCESSES

1. Technical Discussion

The characteristics of emissions, effluents, and solid waste residues will be dependent upon the oil shale processes employed in developing the resource. The specific processes selected will depend on such factors as geology, economics, and governmental regulations.

Oil shale exploration activities are similar to those for coal. Development of the regional appraisal is derived from information on exposed rock formations and extensive drilling and coring evaluations. A large portion of effort centers on evaluation of the Piceance Basin principally by the United States Geological Survey.

The processing of oil shale proceeds in one of two directions: (1) shale can be mined and then processed on the surface; or (2) the rock can be processed underground (in situ) with the resulting liquids (oil fractions) withdrawn by wells. The mining of oil shale can be by surface mining or underground mining technologies.

Surface mining of shale would involve the same activities as for surface coal mines: surface preparation, fracturing and excavation. The drilling, blasting, and excavation technologies for surface coal apply to oil shale with the exception that oil shale zones can be over 1,000 feet thick and the resulting shale surface mines are more like limestone quarries or open-pit copper mines with several working benches.

Underground mining has been the only process utilized to date for oil shale mining in the U.S. and is similar to underground coal mining generally. The shale underground mining process differs from that for coal due to the greater thickness and hardness of producing zones. Underground oil shale mines will probably use the room and pillar approach (on the order of 60 feet square) as the most efficient method for deep mining hard materials. The floor to ceiling clearance will probably range from 60 to 80 feet.

Preparation of the oil shale is necessary since the feedstock for shale processing must be within certain physical limits. The preparation activity will be crushing and sizing depending on the needs of the processing technology to be used. If the processor cannot accept fine particles, these particles would be removed, crushed further, mixed with oil and formed into briquettes large enough to be used. If the processor can accept fine particles, the three-inch material coming from the initial crushing operation is further size-reduced to the maximum particle size that the process can accept but is not screened. After any of the crushing stages, the oil shale may be stockpiled to assure an uninterrupted supply.

Processing of oil shale involves retorting and refining to recover the hydrocarbons present in the shale. The oil shale retorting stage is the part of the process where the major technological choices are being made. Shale oil refining operations will involve a number of processing and product options somewhat similar to those in petroleum refining.

Shale oil is formed by the pyrolysis or distillation of organic matter (Kerogen) found in shale-like rock. The organic material has limited solubility in ordinary solvents and cannot be easily recovered by extraction. Upon strong heating, the organic material decomposes into gas, condensible liquids and residual carbonaceous material remaining on the spent shale. The major retorting steps involve the heating of the solid material to the proper temperature and the recovery of the vapor evolved. However, for a commercially feasible process, it is necessary to consider and properly choose one of the many possible methods of physically moving the solid material through a vessel in which the retorting is to be carried out, as well as many other interrelated variants and operating parameters.

Retorting of oil shale can be classified into four categories: gas combustion (partial gas combustion to supply the heat for the pyrolysis reactions), solid heat transfer, in-ground processes (*in-situ*), and other miscellaneous processes. In an effort to provide an economically attractive process, literally hundreds of retorting processes have been proposed over the years, each of which offers a somewhat different choice of operating conditions. Leading retorting operations developers include: Union "B", Union "SGR", Tosco II, Occidental (*in-situ*), Westco (*in-situ*) and Superior.

2. Program Discussion

A specific R&D program directed toward process control and treatment technology was initiated in 1974. The current EPA program (see Figure 1) encompasses a TRW Study, Colorado State University's Shale Leaching and Hydrology Modeling Project, Radian's Air Pollution Emission Estimates, The University of Oklahoma/Radian's Technology Assessment of Western Energy Resource Development, and cooperative efforts with EPA's Region VIII (Denver). Region VIII's overall activities include: (1) baseline surface water quality data collection; (2) aquatic-terrestrial-eco-system study; (3) instream needs model; (4) air quality monitoring; (5) meteorology; (6) groundwater prediction and modeling; (7) air pollutant emissions from specific oil shale facilities; (8) noise control programs; (9) air quality maintenance plan development; (10) drinking water survey; (11) health impacts of energy related community; (12) socioeconomic impacts; (13) areawide waste treatment management plans (208 Grants); and (14) facilities planning funds (201 Grants).

A preliminary evaluation of environmental impacts of oil shale processing is currently underway. The TRW Study will produce an interim report scheduled for completion in June of 1976. A concurrent effort by TRW is being made to provide an updated assessment including pollutant characterization and results of field testing by July of 1977. The third task will be to provide a manual of practice on the best available control technologies by November of 1978. The year-long effort will consider all previous research and applications of control technology to oil shale development. The fourth task is a concurrent effort with the third task to report on pilot-scale testing of possible control devices and methods by early 1979. The fifth task will be an updated assessment in which the contractor reviews new concepts and state-of-the-art. This effort is to provide the basis for demonstration of advanced pollution control techniques which will be required under federal and state regulations. This assessment is to be completed in 1980. The sixth and final task is to demonstrate advanced pollution control techniques which are adequate for protecting the environment during the evolution of the shale oil industry in the U.S.

3. Projection

Although the coal mining pollution abatement program has existed for many years, the mining for oil shale will result in different requirements for environmental controls. Crude petroleum refineries have also existed for many years and refinery environmental control technology has been developed over a period of years. The problems of environmental control for oil shale crude refineries have not been determined. Retorting of oil shale is a relatively new process which may involve by-product recoveries of metals as well as hydrocarbons. Environmental controls for retorting processes include a full scale demonstration phase which will verify the best control technology then available.

INTERAGENCY PARTICIPATION

Numerous environmental studies are being conducted by governmental agencies. The major activity is related to the mining or *in-situ* retorting of shale oil crude. The Energy Research and Development Administration demonstration programs include: Rock Springs Oil Production Test, Simulated Gas Production Test, Demonstration Test of Modified Horizontal Oil Production, Development of Fracturing Methods and Conversion of Shale Oil to Fuel Products. The State of Colorado and the State of Utah have Air Quality Monitoring Programs underway. The United States Geological Survey is involved in Air Quality Monitoring and Ground Water Monitoring programs (as they relate to the Federal Leases), and geochemical and groundwater modeling efforts in Colorado and Utah. A Surface and Underground Mining Analysis is being conducted by the Department of Interior (Bureau of Mines) which includes deep mining (methodology and costs), open pit (one pass), and modified *in-situ* studies.

RESOURCE ALLOCATION

The oil shale industry is a continuing development which dates back to the 1850's. The U.S. EPA's program began in 1969 on environmental aspects of oil shale development. The resource allocation for the oil shale environmental assessment project (the TRW Study) within the EPA-OEMI R&D program is as follows:

FY74	FY75	FY76
-	$460K	$192K

The allocations shown above exclude EPA resources devoted to oil shale mining/extraction R&D (these are covered in another Paper) and exclude the resources expended by EPA's Regional Offices.

CONCLUSIONS

The potential for oil shale development in the United States appears to be great. The oil shale deposits are estimated to contain 2,200 billion barrels of oil in the richer shale (greater than 25 gallons/ton) and over 40,000 billion barrels of oil in the intermediate shale (10 to 25 gallons/ton). The richer shale formations are located primarily in Colorado, Utah and Wyoming. The intermediate shale can be found throughout the Midwest. The potential for environmental impact from oil shale development is also great.

The characteristics of emissions, effluents and solid waste residues will be dependent upon the oil shale processes selected by economic, and geologic considerations. The treatment control technology will be developed to minimize the environmental damage by process developments.

The overall strategy for environmental control R&D by EPA encompasses exploration, mining, preparation, processing, reclamation and transportation. The program includes environmental impact analyses pollutant characterization, available control technology evaluations, and demonstration of pollution control techniques.

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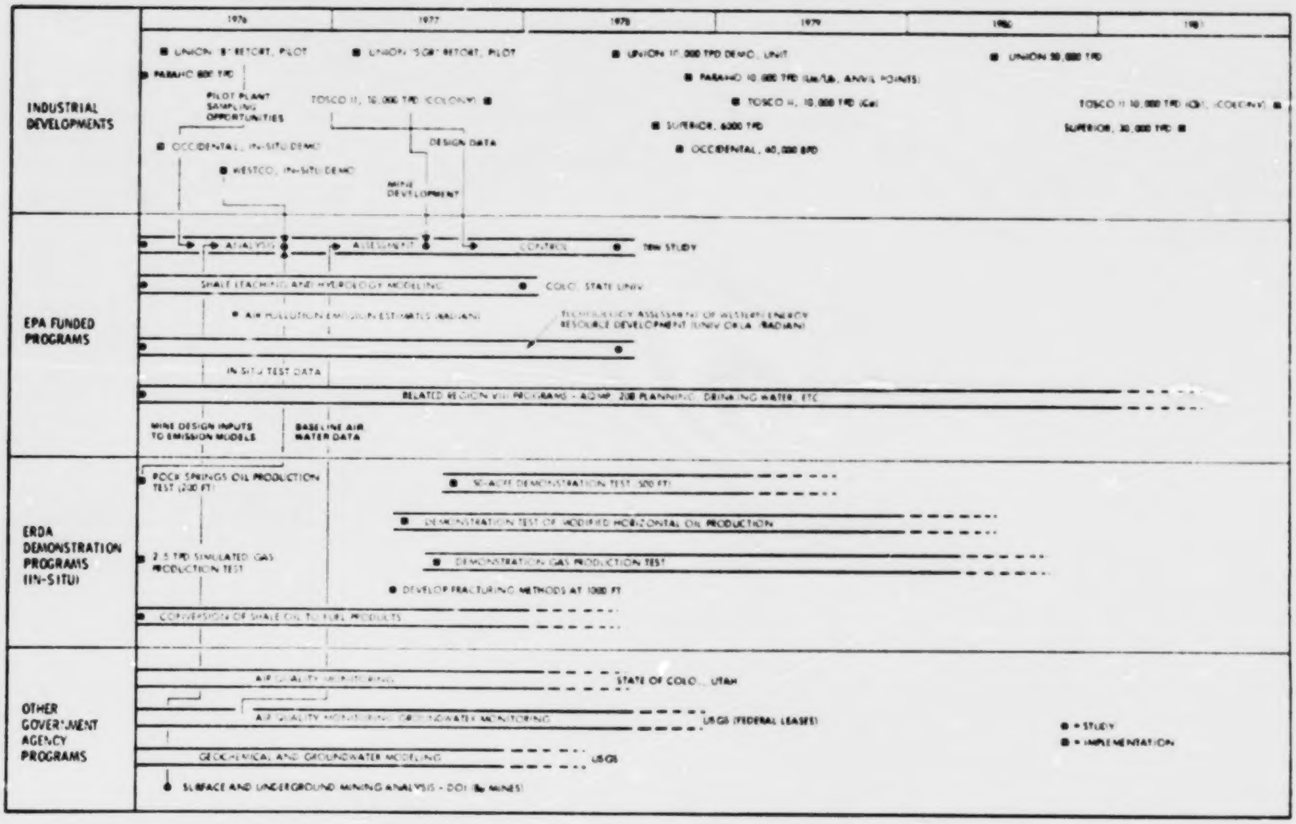
Figure 1. - Shale Oil Development Program



Program for Environmental Aspects of Synthetic Fuels

William J. Rhodes
Industrial Environmental Research Laboratory-RTP
Office of Research and Development
Environmental Protection Agency
Research Triangle Park, N. C.

Introduction

Using the Dixie Lee Ray energy report as a basis, we are, as a Nation, over two years into a commitment to utilize more fully our own natural resources and to become less dependent on foreign sources of energy. These natural resources include coal, oil, oil shale, solar energy, water (including tides), wind, geothermal energy and nuclear energy among others. It is important that these resources be developed with a proper, but presently unknown, balance among the various alternatives to satisfy our real needs. It is no less important to adequately protect our environment while striving to achieve and achieving our energy goals. Energy for the sake of energy is not an objective; but rather energy for maintaining and improving the quality of life should be an objective. In this regard, knowledge of environmental consequences of our Nation's energy development and a free and open evaluation of the alternatives are necessary, consistent, and intertwined ingredients of attaining an acceptable quality of life.

Within the Federal Government the Environmental Protection Agency has the primary responsibility to assess the environmental factors of the energy technology and to develop and/or aid in the development of controls to protect the environment from adverse effects. To be consistent with the overall objectives, environmental factors include both pollutant and nonpollutant effects such as land use and socio-economic considerations. Likewise, environmental controls include not only add-on effluent controls but also such items as different strategies for handling potential effluents and technology for increasing thermal efficiency. The latter have many environmental side benefits (e.g. reduced thermal pollution and reduced quantity of fuel required for a given output).

It is obvious that development of energy systems without the consideration of environmental factors will probably result in unsatisfactory total systems from an environmental view and will require last minute, and therefore probably costly and inefficient, add-on controls in order that the systems may be commercialized. A considerably more rational approach is to start with a low level of environmental concern during initial bench scale process development and continually increase the environmental awareness until a comprehensive program is operational during pilot and larger operations. As the environmental evolution proceeds, the development and improvement of control technologies having common applicability to many conversion systems will be advanced early while more process specific environmental controls await more detailed data. This will permit sufficient time to allow development and demonstration of needed efficient controls (add-on, process modifications, strategies, etc.) in time for process commercialization.

For various technologies, the environmental responsibilities are addressed by different groups within EPA. The environmental factors in the production and utilization of synthetic fuels from coal constitute one element of the responsibilities of the Fuel Process Branch of EPA's Industrial Environmental Research Laboratory (IERL-RTP). For several years prior to our Nation's latest commitment, this Branch (under its predecessor names) has had a significant role in evaluating the environmental aspects of synthetic fuels. This program is briefly presented in the following paragraphs.

IERL-RTP: Synthetic Fuels Program

The program of environmental aspects of synthetic fuels is divided into the areas of environmental assessment and control technology development.

The overall objective of the environmental assessment category is to ensure an environmentally sound synthetic fuels industry. To accomplish this, past and future work utilize existing information to perform multi-media environmental source assessments. Existing and possible future Federal, state and local standards and guidelines are reviewed to provide a baseline for the assessments. As information gaps and needs are identified, programs are initiated to acquire the data that are necessary to fulfill the needs. Acquiring the necessary data is an all important task. It requires knowledge of existing data, co-operation of plant operators, identification of sampling and analytical techniques, test program development, and an overall data analysis scheme. These data may be obtained from in-house studies, process developers, ERDA, plant operators or other sources depending on the most appropriate arrangements for the situation. The environmental assessment program must include prioritization of potential pollutants and streams to be analyzed. These evaluations are necessary for so called steady state conditions, for normal transient conditions such as startup and shutdown, for accidental releases, and for malfunction situations. The data will then provide a basis for updating the environmental source assessments. This information will be exchanged with other involved groups such as those concerned with health effects, atmospheric effects, ground water effects, etc. As feedback information is obtained from these areas, the data will be integrated into a total environmental assessment.

Table 1 contains an outline of some of the components of the environmental assessment area which have evolved from past and present work. The major contract areas are divided along technology lines; i.e. low Btu gasification and its utilization, high Btu gasification, and liquefaction. The prime contractor in each area is responsible for conducting and integrating the required efforts to properly assess the area. In addition, the contractor will provide support as necessary to other interested groups via publishing of manuals, meetings, and special documentation.

Within the environmental assessment category are a number of supporting activities whose results would complement and be used by the major contract areas. Input material characterization (such as coal analysis) is the common starting point for material balances especially as it relates to potential pollutants or pollutant forming constituents in the material. Theoretical and practical evaluations of pollutants' form and fate in multimedia systems would provide important data acquisition guidance and assessment information. A major potential for support exists in the interagency agreement with ERDA for processes they are supporting. These support areas could include a review of the types of environmental data being obtained, analysis of existing data, identification of streams to be analyzed, review and development of methods of analysis, conduct of a test program, and analysis and correlation of results to establish the paths and quantities of potential pollutants in each synthetic fuel system. Table 2 summarizes some of these activities.

The overall objective of the control technology development category is to ensure that needed environmental controls are available for the synthetic fuels area. This requires utilization of information from many sources such as environmental standards, environmental assessments, control developers and users, and independent evaluations. This work includes identification of environmental control technology alternatives; evaluation of the applicability of existing environmental control methods to known and potential problems; design and cost studies; field testing of existing control methods for acceptability; in-house experimental evaluations; and evaluation, development, and demonstration of new/novel control methods.

Table 3 contains an outline of some of the components of the control technology development area. The major contract areas are divided so as to cut across process technology lines. Thus each prime contractor is responsible for low and high Btu gasification and liquefaction for his respective work area. The major work areas divide a given technology roughly along the following lines: pretreatment and wastes, converter output streams, products and byproducts.

As with the environmental assessment category, there are several supporting tasks. Operation of flexible in-house facilities will permit independent and timely evaluations of potential controls for their effectiveness, energy efficiency, and effluents. Studies of reaction mechanisms of potential pollutants in synthetic fuels would aid in attaining more environmentally sound fuel products. An interagency agreement with ERDA has the potential for supplying information on environmental control systems design characteristics, operational characteristics, stream quantification, material and energy requirements, and capital and operating costs. In addition there is the potential for testing new environmental control systems on ERDA supported synthetic fuel plants. Table 4 lists the activities in these areas.

Process Items of Preliminary Concern

The IERL-RTP source assessment is not a fixed set of requirements in its data acquisition phase but is a plan which will evolve and be modified for each specific situation. The evolution process will apply both to techniques in sampling and analysis and to re-prioritization of constituents/streams to be investigated. At the time of this writing, a report which considers inputs from all sections of IERL-RTP has not yet been prepared but is under consideration. However, analytical test plans have been published as preliminary guidance for use in synthetic fuels applications. One of these plans was written by Exxon Research and Engineering Company under contract to EPA (1). In this plan, five factors were considered: (1) the potential environmental impact of a pollutant, (2) available compositional data on commercial coal conversion streams, (3) coal compositions, (4) process considerations, and (5) materials considered to be environmental hazards. Table 5 is a modified list of the resulting items for initial analysis.

For the model coal conversion facilities used in the Exxon study, a minimum of about twenty streams would have to be analyzed. This minimum number is an idealized number for a theoretically near perfect system. In actual practice additional stream analyses will be required. As a maximum approximately seventy streams were identified for analysis to achieve pollutant material balances.

Summary

Our Nation has embarked on an energy program which strongly emphasizes use of our own coal resources. One use is to convert the coal to synthetic fuels; however, the environmental detriments of such programs must be thoroughly analyzed and alternatives weighed. Inadequate piecemeal environmental data do exist and will be used as initial guides. IERL-RTP, based on a continuing program in synthetic fuels, has initiated cohesive efforts to obtain necessary information and perform integrated environmental assessments. With cooperation among industry, university, government agencies, and other interested parties, these efforts will provide an important, credible contribution to the quality of life.

References

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Table 1. - Environmental Assessment

Major Contracts

- Low Btu Gasification and Its Utilization
- High Btu Gasification
- Coal Liquefaction

Support Areas

- Input Material Characterization
- Key Multi-Media Pollutant Systems Studies
- Environmental Assessment of Specific Control Processes
- Special Testing
- ERDA Interagency Agreement

Table 2. - Environmental Assessment Activities

General Support

- Dissemination of information (symposia)
- Program support contractor - systems analysis, program coordination
- Overseas data acquisition program
- Multi-media pollutant system studies
- Special testing, e.g. biological

Input Material Characterization

- Coal analyses for potential pollutants
- Synthetic liquid analyses for potential pollutants
- Other materials input to process and their potential pollutants

High Btu Gasification

- Summary report on technology reviewed to date
- I.A. with ERDA - interface with their environmental activities
- Assess specific control processes for environmental impact
- Gas cleaning test rig (in-house)

Low Btu Gasification

- Summary report on process technology
- Alternative high vs. low temperature cleanup in combined cycles
- Report on environmental factors in retrofit of fuel gas
- Prime contract for data acquisition and assessment
- Environmental source assessment of overseas commercial installation (South Africa, Poland, Yugoslavia)
- Assess specific control processes for environmental impact
- Gas cleaning test rig (in-house)

Liquefaction

- Summary report on process technology
- Report from P&M on SRC process
- Prime contract for data acquisition and assessment
- Assess specific control processes for environmental impact
- Coal hydrogenation test rig (in-house)

Table 3. - Control Technology Development

Major Contracts

- Fuel Converter Output Streams
- Products and By-Products
- Fuel Storage, Preparation and Feeding and System Wastes

Support Areas

- Evaluation Facility, In-House
- Pollutant Reactions in Synthetic Fuels
- Specific Control Process Development and Evaluation
- ERDA Interagency Agreement

Table 4. - Control Technology Development Future Activities

- Control Technology Evaluation
  - Simultaneous hydrodesulfurization/hydrodenitrification of synthetic liquids
  - Hydrodenitrification of synthetic liquids
  - General program support for systems analyses, reviews, etc.
  - Technical/economic studies of control methods and applications
  - New control process evaluation
  - Test criteria specification for control process examination
- New/Novel Control Method Development
  - Pilot plant studies of dolomite cleanup system
  - New gas treatment process development
  - New liquid treatment process development
  - New solid waste treatment process development
  - Final disposal technique development
  - Fugitive emission control technique development
  - Prime contractors' control development areas
- Existing Control Method Field Testing
  - Control technology evaluation of foreign conversion facilities
  - Interagency cooperation with ERDA on field testing of existing control systems
  - Prime contractor's field testing for existing control techniques
- Field Demonstration of Control Methods
  - Interagency cooperation with ERDA on field demonstration of control systems
  - Prime contractors' field demonstration of control techniques
- In-House Experimental Studies
  - Construction/operation of in-house acid gas cleanup facility
  - Construction/operation of an in-house coal hydrogenation control unit
  - Construction/operation of an in-house oil treatment facility for denitrification

Table 5. - Possible Pollutants from Coal Processing

Metals

As
Ba
Be
Ca
Cd
Cr
Fe
Hg
Li
Mn
Na
Pb
Sb
Sn
V

Gases

AsH_3
H_2Se
Fe, CO and Ni Carbonyls
SO_2/SO_3
NO_x
COS
H_2S
CH_3SH
NH_3
H_2
CO
CH_4
HF
HCl
CO_2

Polynuclear Aromatics

Benzo(k)fluoranthene
Benzo(b)fluoranthene
Benzo(a)pyrene

Benzo(e)pyrene
Perylene
Benzo(ghi)perylene
Coronene
Chrysene
Fluoranthene
Pyrene
Benzo(ghi)fluoranthene
Benzo(a)anthracene
Triphenylene
Benzo(j)fluorenthene

Other Organic Materials

thiophene
CS_2
phenols

benzene
toluene
xylene
oil
acids
aldehydes
naphthalenes

Inorganic Ions

CN^-
SCN^-
F^-
$S^=$
$CO_3^=$
$SO_4^=$
Cl^-
$PO_4^{\equiv}$
NO_3^-

Particulates

Other Analyses

Coal Analysis

Moisture
Ash
Volatile Matter
Fixed C
S
P
C
H
N
Cl
Calorific Value
Fusibility of Ash

Water Quality Indicators

Specific Conductance
pH
COD
BOD
TOC
Residue
Dissolved Oxygen
Suspended Solids
Dissolved Solids
Turbidity
Color
Oils

Special Testing

Bioassay
Health effects
Material effects
Ecological effects

DISCUSSION FOR FUEL PROCESSING SESSION

Question: This question relates to the project on lignite dehydration and fixing. Does the transport of the high mixture content coals present a volatility problem with a potential for fires? What is being done in the area of fire prevention?

Panel Response: The process involves pelletizing the lignite and heating to reduce moisture content from approximately 40 to 10%. The BTU content on a weight basis and the transportation costs are improved accordingly. If these hardened pellets can be stabilized, or something of this nature, the material will not spontaneously combust as will lignite in the natural state. The cost of this process will be expensive as are the alternatives such as scrubbing. Some such treatment will be necessary to meet new more rigorous environmental standards. Also to be considered, lignite represents a tremendous reserve, it's easy to mine and it's right on the rail line.

Question: Are various governmental agencies devoting resources to projects which consume a great deal of environmental-energy monies when there is also sufficient incentive to industry to do the work?

Panel Responses: At this stage, there is a need for governmental support. Especially with the situation existing with capital, industry can be expected to be reluctant to commit millions of dollars for a coal gasification plant that would produce oil at an equivalent basis of about $20 a barrel. Though the OPEC price has been rising, there is no assurance that it will continue to rise or that it will not be reduced. With the world situation what it is, the investment would be too risky without some government support at the marketing end. It is much cheaper for government to invest at the R&D end at this time.

In some areas, the regulatory incentives do exist for industry development. Parallel efforts are being pursued in flue gas scrubbing technology by government and private industry. In some cases technology is forcing legislation. The Clean Air Act of 1970 falls into that category. According to the language of the Law, the new source performance standards take cost into account, and it is incumbent upon the government to prove that such cost-effective controls are actually available for stationary sources.

EPA and the Bureau of Mines have been jointly promoting physical coal cleaning since 1969. At that time, industry was unwilling to commit the necessary funds to such a program. Now the public utilities have announced intentions to demonstrate a full-scale plant for physical coal cleaning. It will probably be 1980 before the technology is actually demonstrated. In any event, EPA does not have the money to fund the demonstration on its own, but will probably aid in the effort. It seems that a mix of industry and government participation in this case will be required for development and demonstration of this and other technology.

Question: The Energy, Research and Development Administration has a number of programs aimed at improving the efficiency of various types of heat engines, including several advanced cycles. Possibly one way of improving efficiency will be through increased temperatures with the combustion process. Does EPA have a program to control the nitrogen oxide problem that would probably be associated with the higher combustion temperatures?

Panel Response: EPA has a significant program for the control of nitrogen oxides. Next year expenditures will be about six million dollars. It is true that high combustion temperatures lead toward higher levels of nitrogen oxides. Another session will address conservation measures which are concerned with processes other than those employing greater thermal efficiencies.

Fluidized bed combustion of some advanced power cycles does not require higher temperatures and, therefore, does not result in higher NO_x levels. The main problem in these processes is one of too much corrosion, not NO_x formation. Long-term testing will be required for these programs, but there is a good possibility that thermal efficiencies will be improved without increased NO_x generation.

Question: It is noted that much coal processing work is devoted to removal of sulfur and sulfur compounds. Is work also being done to remove other compounds which would reduce ignition and corrosion problems in the combustion process?

Panel Responses: Much of the fluidized bed combustion work has been addressed to SO_2. However, work currently being initiated will include the full range of possible pollutants. In addition to fluidized bed combustion, this work will include coal gasification and better energy processes.

Physical coal cleaning removes more than sulfur compounds. Heavy fractions and trace metals may be reduced by as much as 50%.

Question: What is the cost per ton of chemically cleaned coal?

Panel Response: There are a number of chemical coal cleaning processes which are currently being examined. However, the state-of-the-art is such as to leave a tenuous feeling about the cost effectiveness. Costs range from slightly more than physical coal cleaning to costs in range of synthetic fuels. We are not really in a position to arrive at good cost figures for chemical coal cleaning at this stage in process development.

Question: In a previous question, the cost associated with processing lignite was discussed. Has there been an analysis of what the cost would be to add water to the lignite and pump it in a slurry rather than to dehydrate it and move it in pelletized form?

Panel Response: While it may be a possibility, pipeline transmission of lignite has not been evaluated.

Question: Does the proprietary nature of data on the various synthetic fuel processes limit the availability of this data and, consequently, the ability to evaluate these processes?

Panel Response: Proprietary data can be a problem. However, data availability can also be a problem between governmental agencies with no proprietary interests.

Question: Is there a target date for when standards will be set for gasification and liquification?

Panel Response: No.

Question: Mention has been made of an atmospheric fluidized bed combustion plant which will be constructed shortly. Should standards be set before that demonstration?

Panel Responses: The Office of Air Quality Planning and Standards has been working on coal gasification for the last six months. Drafts of proposed standards have been prepared. The timing of such standards is a matter of some debate. One school of thought suggests that a relatively large plant should be on-stream first so that hard data is available for the preparation of the standards. The other school of thought is that early standards will provide process developers with a target.

Sufficient data is not available to set good reasonable standards. Some guidelines, however, would probably be an assistance to the industry before the plant went on-stream.

Question: The control technologies appear to be addressed in a discrete fashion from extraction to fuel processing and combustion. Are there any attempts being made to compare approaches on a total system basis rather than comparison of each process independently? Secondly, do the research studies reported here consider the lead times for commercial availability?

Panel Response: Studies concerned with the total system approach will be covered in the following sessions on Integrated Assessment.

Question: One of our major energy development scenarios is based upon fluidized bed combustion. When can a full-scale plant in the thousand megawatt range be feasible? Can such a prediction be made?

Panel Responses: A full-scale plant must be preceeded with a demonstration plant, such a plant would probably be in the 200 megawatt range. Two studies gave conflicting advice on the desirability of starting the conceptual design of a demonstration plant now. Even when this conflict is resolved, at least four years will be required to build the demonstration plant. Anything larger would be started later, in say five years. Utilities are likely to be conservative in their commitments, and may require more than one demonstration plant before they consider the technology sufficiently acceptable, to design and construct such a plant with their own funds.

Fluidized bed combustion systems are envisioned as being commercially available in the early 1980's. In the case of pressurized fluidized bed combustion systems, in the mid 1980's.

With regard to integrated assessment, it should be noted that many trade-off studies have been accomplished. These studies indicate that there is a substantial amount of missing information relative to pollution control cost and the cost of new development technology. Any effective integrated assessment in assigning risks and costs to each of our alternative strategies will not be possible until some of the current environmental assessment programs are completed. It will probably be two to three years before the information necessary for an integrated assessment is possible.

Question: Has magneto-hydrodynamics been discussed in this symposium?

Panel Response: In some people's opinion, MHD is an idea whose time has come and gone.

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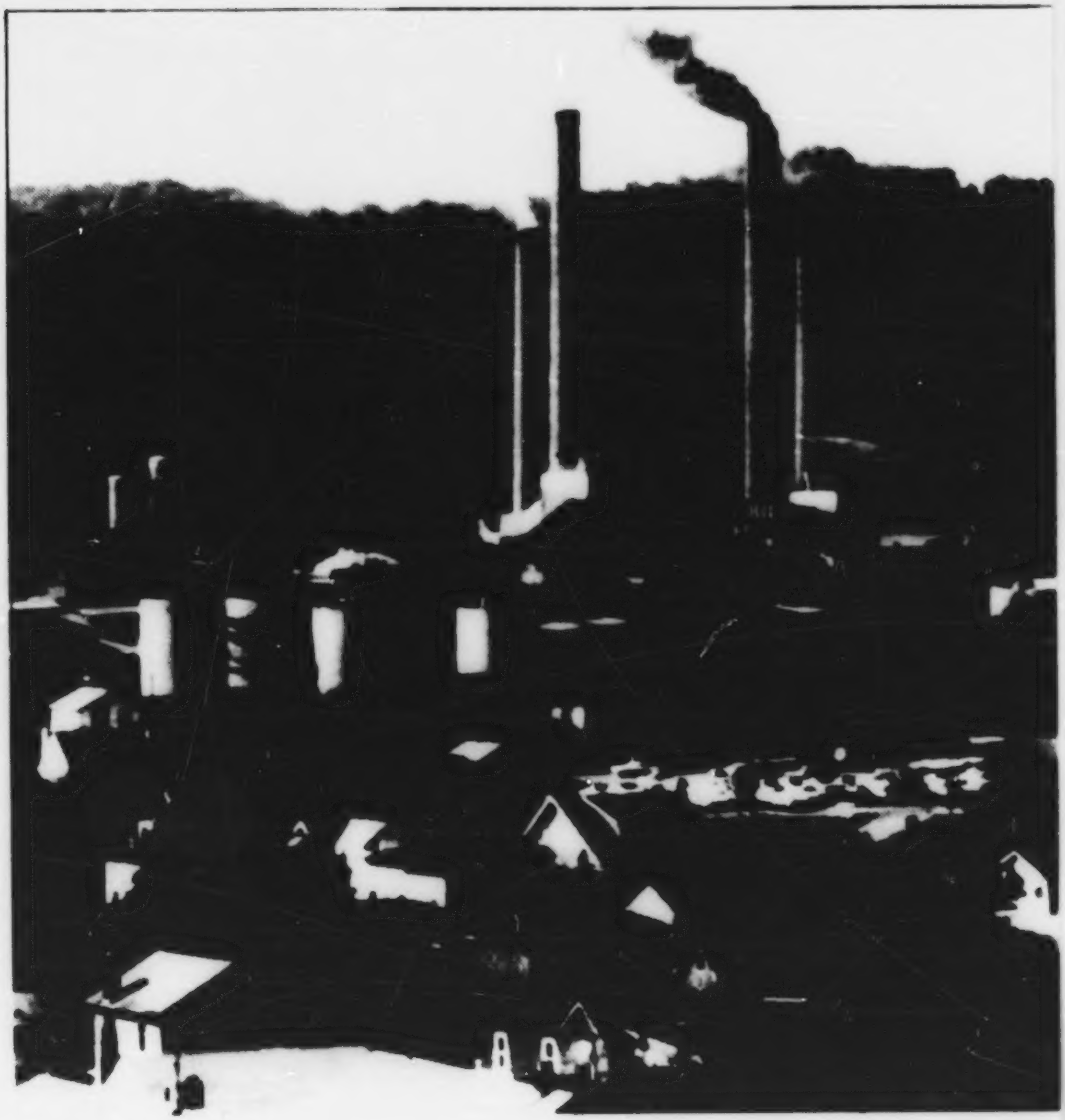
CHAPTER 10

FLUE GAS TECHNOLOGY



INTRODUCTION

One of the major energy related environmental problems concerns the need to control the emissions produced during the combustion of fuels. The major pollutants emitted in the flue gases of stationary sources are the oxides of sulfur and nitrogen, and particulate matter.

The 1970 amendments to the Clean Air Act have provided the authority and much of the impetus for development of flue gas technology directed at removal of pollutants. These technological strategies make a distinction between existing and new sources with standards established which are intended to result in overall improvement to the ambient air quality.

Reduction of the atmospheric emission of the oxides of sulfur may be accomplished by removal of sulfur from the fuel or during combustion in processes such as the fluidized-bed. Flue gas desulfurization is aimed at removal of sulfur compounds which are present in the stack gas and would otherwise be emitted to the atmosphere. While there is probably some best place, or best combination of places to remove sulfur, flue gas treatment appears promising. It also has the advantage of near term availability and compatibility with other flue gas treatment which may be necessary.

Flue gas desulfurization processes are commonly classified as either regenerable or nonregenerable, depending upon whether the absorbent material may be recycled after sulfur removal. Regenerable processes typically produce a saleable product such as sulfuric acid or elemental sulfur. Nonregenerable processes produce a waste product. There are other differences between the basic processes in terms of cost, market availability, reliability and other relative advantages, however, both are effective in sulfur removal.

A related technology is concerned with removing nitrogen oxides from stack gas emissions. Nitrogen oxides are also emitted during combustion from mobile sources such as the automobile. The control strategy is to attack each source independently, with most emphasis on stationary sources where the best results are expected to be achieved.

As was the case with sulfur pollutants, there is an alternative to removal of nitrogen oxides from the stack gases. The formation of these oxides may be reduced by modification to conventional combustion processes, generally involving lower combustion temperatures. At present, however, flue gas treatment for removal of nitrogen oxides may appear to be more promising because of the higher removal efficiencies and the more advanced state of the technology.

A third major technology is associated with the removal of flue gas particulate matter. Fine particulates, especially, are a health hazard because of their ability to circumvent the body's respiratory filters. They tend to remain airborne for long periods and distances and contribute to a number of undesirable effects. Removal techniques include filtering, precipitation and absorption. Each has various advantages and disadvantages often depending on particle size or stack gas volume, pressure or temperature.

All of the flue gas cleaning technologies share a common problem. The cleaning process produces a waste material which will require disposal. These wastes are of large volume and potentially environmentally troublesome. Waste disposal is a major consideration of the flue gas cleaning technologies.

FLUE GAS TECHNOLOGY

FRANK T. PRINCIOTTA

Director, Energy Processes Division
Office of Energy, Minerals, and Industry
U.S. Environmental Protection Agency

Let me begin with EPA's Flue Gas Cleaning Program. First of all, the Clean Air Act is the primary driving force for much of the research and development activity in the Flue Gas Cleaning area. Figure 1 summarizes the impact of the Clean Air Act on flue gas cleaning technology. As many of you know, the Act calls for statutory requirements for environment control of new and existing sources. Criteria pollutants are designated for which ambient air quality control was to be achieved by mid-1975. According to the Act, the pollutants that were selected were considered the most troublesome pollutants identified, namely: SO_2, NO_2, particulates, hydrocarbons, carbon monoxide and photochemical oxidants.

As most of you know, stationary combustion sources are the primary cause of SO_2 emissions and total suspended particulate emissions; whereas, NO_x emissions result from both mobile and stationary combustion sources.

The Clean Air Act also called for implementation plans which basically laid out the control strategies for existing sources to control each of these pollutants so that ambient air quality standards would be met.

In addition, selected industries were designated for New Source Performance Standards (NSPS): the emission controls were to be based on the best available control technology.

Figure 1 includes NSPS for large coal-fired steam generators for SO_2 TSP, and NO_2. To give you a point of reference, uncontrolled emission factors associated with a high-sulfur coal fossil fuel plant are compared with the NSPS values. What this indicates is that a relatively high degree of control is required for total suspended particulates; 98 plus percent removal is required. The SO_xNSPS calls for 75 or 80 percent removal from a typical high sulfur coal; whereas, NO_x control involves only about 30 or 35 percent control.

Figure 2 lists the primary pollutants for which flue gas cleaning represents an important control option. On the left-hand part of the figure, we've listed the appropriate standard, both NSPS and Ambient Air Quality Standards (AAQS). Potentially hazardous materials, i.e., pollutants other than the criteria pollutants are also included; basically, the magnitude of this problem is undefined.

We also list the type of control technology available to control the particular pollutant. We emphasize here, the "near term" technology. For the pollutant SO_2, for example, we include coal cleaning and flue gas desulfurization. For NO_x, we include combustion modification technology and flue gas treatment, both of which, we'll discuss a little later. I should point out that for the purpose of this session, we're going to assume that combustion modification for NO_x control is a flue gas cleaning technique.

For particulates, the typical control technologies which are here now are: ESP's, wet scrubbers, and baghouses.

One of the columns on this particular figure shows the development status of each control technology: from pilot scale testing, all the way up to commercial demonstration.

With most of these flue gas cleaning processes, we end up with a secondary residual, which one has got to be concerned about. For example, in SO_2 control, a sulfur compound is produced for either sale or disposal. Generally, this is a throwaway sludge material, or sulfuric acid or elemental sulfur.

As the figure indicates, there are possibilities of additional future standards. For example, ambient sulfate standards (if promulgated) could very well effect the kind of control technology needed for SO_2, emission control. There may also conceivably be nitrate and fine particulate standards which could require revision of emission control requirements for NO_2 and TSP.

Figure 3 shows the rough magnitude of funding for our program, both in terms of the overall program and for individual program areas. You can see we've shown funding for fiscal years 1975, 1976, 1977, and 1978-1980. I have to caution everyone that these numbers are estimates and are not firm. The funding levels for FY 77 and beyond are particularly rough estimates since detailed planning has not yet been accomplished.

But, I think that there are some trends here worth mentioning. First of all, the overall funding in this area is reasonably high relative to the rest of the energy/environmental interagency program. And in fiscal year 1975, the interagency programs expended about $37 million on flue gas treatment technology. As you can see, over half of this was in the flue gas desulfurization area. The reasons this is so large is because it included funding for the last two FGD demonstration programs to be co-funded by EPA.

You can see from this figure that flue gas desulfurization funding is decreasing sharply with time, and NO_x control is increasing with time. Other program areas including fine particulate control technology are remaining roughly constant with time.

Flue Gas Desulfurization

I would like to discuss the flue gas desulfurization R&D program. This is probably the most controversial of the flue gas cleaning technologies, probably it's the one with the most immediate commercial impact. This technology has received much publicity and has vocal proponents and opponents.

EPA considers several of these processes to be commercially available and viable. Particularly, lime, limestone, and Wellman Lord systems are considered demonstrated technologies. Over the last several years, the utility industry has been quite active and has installed on the order of 42,000 megawatts of flue gas desulfurization capacity. This compares with a total coal-fire capacity, presently, of about 150,000 megawatts. Roughly, three-quarters of these 42,000 megawatts have been lime or limestone FGD systems. At this time, many utilities are (albeit reluctantly) installing FGD systems, particularly on new coal-fired units.

As many of you know, there are significant improvements that can be achieved in these processes and that's what our R&D program hopes to achieve. We can, for example, decrease the alkali utilization--the utilization of lime or limestone. Obviously, the less limestone we use, the less input material is required and the less throwaway sludge is produced.

Also, present systems are quite expensive and there are process improvements which can reduce the capital and operating costs. We also can improve the properties of the throwaway product. By improving the properties of the throwaway product via oxidation or chemical treatment disposal, problems can be eased and simple landfilling of the materials may be acceptable.

Also, we can minimize energy usage: FGD systems use in the order of from three to seven percent of the power plants electrical capacity just to run the scrubbers. There are significant improvements that can be made in this area.

Figure 4 summarizes the EPA flue gas desulfurization demonstration program. The Clean Air Act calls for EPA to demonstrate promising air pollution control technologies; this figure lists and describes the major FGD demonstration programs sponsored in total or in part by EPA.

Now, I'd like to briefly summarize the non-regenerable (throwaway product) portion of our flue gas desulfurization program. Figure 5 summarizes the major activities in this area which are divided into three major categories: the lime-limestone (Shawnee) program, Double Alkali program, and the Louisville Gas and Electric lime scrubbing program.

The lime, limestone Shawnee program is jointly run by EPA, TVA, and Bechtel Corporation. Basically we're operating two 10-megawatt equivalent scrubbers and two small 0.1-megawatt pilot scrubbers which support the larger facilities.

Important test results were generated as early as 1972, and since that time we've learned how to operate these systems reliably with lime and limestone despite formidable scrubber and mist eliminator scaling tendencies. We've identified these scaling problems as being probably the most difficult problems associated with closed loop operation. I can give a lot of detail on this, but suffice it to say, we have these problems under control over the last several months of the program and parameters for reliable operation have been identified.

Also, our small pilot test program has identified a new mode of operating lime and limestone systems called unsaturated operation. This basically means we operate so that the liquor associated with scrubber slurries is unsaturated with respect to calcium sulfate. For those of you familiar with the technology, this means that we can eliminate the gypsum scale problem that has plagued many of these systems over the years. We are now attempting to demonstrate this unsaturated operation at the larger (10 Mw) pilot scale level.

The Shawnee results have indicated that limestone utilizations of from 85-90% are achievable; substantially decreasing the quantities of sludge produced. We have also initiated a program at Shawnee to evaluate the commercially available sludge fixation processes. As you may know, the promise offered here is to develop technology that will allow us to transform, a difficult to settle, sludge material into an acceptable landfill material.

Also, there seems to be evidence that we can get in excess of 95 percent SO_2 removal with lime-limestone systems. This can be important in the event that SO_2 emission standards are tightened.

We want to produce gypsum as opposed to sludge. We want to look at modes of minimizing energy usage. And TVA has been active in developing a computer program which would hopefully be able to input data on process applications and output preliminary design and relevant cost information.

A program of more recent vintage is the double alkali portion of the non-regenerable FGD program. EPA has sponsored bench studies, pilot studies, and most recently, prototype studies on a 20 megawatt unit. Based on the success of these studies, the double alkali process has been identified as having significant potential advantages over lime and limestone scrubbers. The same materials go in, generally, and the same type of throwaway sludge is produced. What happens in the middle, i.e., the scrubbing and regeneration steps are quite different. There seems to be potential reliability, cost, and sludge quality advantages over the lime-limestone systems.

As Figure 4 indicated earlier, EPA will cosponsor a program with a utility to demonstrate the selected double alkali process on a greater then 100-megawatt high-sulfur coal application. We have received proposals for evaluation and a decision will be made on this quite shortly.

Briefly, we have just initiated a program with Louisville Gas & Electric who has a 70-megawatt lime scrubbing system. We will be performing reliability and characterization tests, as well as a sludge disposal study on that full-scale, quite successful lime scrubbing unit.

Figure 6 summarizes our activities in the regenerable flue gas desulfurization area. This program involves developing FGD processes which produce no waste products, just saleable sulfur products. Toward that goal, we've demonstrated a magnesium oxide scrubbing unit at the Boston Edison's Mystic Station (Figure 4). That system started up in early

1972, and it's a 155-megawatt oil-fired boiler. The end product is sulfuric acid. To summarize the programs, many solids handling problems were identified. However, toward the end of the program in 1974, reliability did improve substantially. The process shows quite a bit of promise. However, additional full-scale experience will be necessary before this process can be considered commercially available.

EPA has also participated in Potomac Electric Company's test program on Mag-ox as a coal-fired unit. Unfortunately, the results are inconclusive. We may also participate in the Philadelphia Electric Eddystone Station coal-fired demonstration which represents the only ongoing magnesium oxide project active in the U.S.

With regard to the Wellman Lord process, this is the sodium scrubbing and thermal regeneration process that was included in Figure 4. This technology has been applied quite successfully in Japan, on oil-fired boilers burning high sulfur oil up to 220 Mw in size. It remains to be demonstrated on coal-fired boilers. EPA has co-funded with Northern Indiana Public Service Co. for a 115-megawatt coal-fired Wellman Lord unit which is almost completed. Start-up is expected during May of this year.

EPA has gone out on bids, soliciting proposals from utility/vendor combinations regarding attractive second generation regenerable systems. The goal here are systems that have performance, cost, and other advantages over first generation regenerable systems such as magnesium oxide and Wellman Lord systems. Several very promising candidates have been identified, and a final selection of the utility/process supplier team for the demonstration program will be made relatively shortly.

Other programs, I'll just mention briefly, include the Catalytic Oxidation demonstration program. We've got serious hardware problems with this project and there's real question as to whether or not this program will be brought to a successful conclusion.

Also, we are working with the U.S. Bureau of Mines on a sodium citrate FGD process. Right now we're close to what could be another demonstration for a regenerable process. We are also evaluating a potentially promising process with TVA: the ammonium scrubbing bisulfate process.

Waste and Water

Figure 7 summarizes the major elements of the waste and water program. As I indicated earlier, inevitable with a flue gas desulfurization system, you have worry about the sulfur product, it's either sold or disposed of, and as I indicated earlier, the primary thrust of the utility today has been toward the throwaway systems. Therefore, we've got to be concerned about environmentally acceptable flue gas desulfurization sludge disposal.

Also, flue gas cleaning includes particulate control, and obviously, that means collection of ash; therefore, we're also looking at ash disposal.

Let me just briefly attempt to mention the major elements of the FGD sludge program. We're looking at improving the properites of FGD sludge by oxidizing the sludge to produce gypsum yielding a better settling material. Also, we're going to evaluate commercially available fixation processes which harden these sludges to facilitate disposal.

We're characterizing sludges--what are the properties of sludge versus operation parameters. TVA and Aerospace Corp. are gathering data in this area.

We're looking at the interaction and input of sludge disposal on the environment. We have a program with the Army, and the Shawnee Program is gathering information in this area.

We're also trying to generate a data base for a sludge disposal standard. Finally, we're looking at ways of perhaps utilizing sludge by turning it into a saleable product.

As I indicated, TVA also has an important program looking at the environmental impact of ash disposal as well as characterizing ash as a function of different types of parameters.

Tennessee Valley Authority FGD Program

I should point out that at this juncture that the Tennessee Valley Authority (TVA) is a major participant in the flue gas desulfurization program with EPA. In fact, TVA has been a major partner with the Environmental Protection Agency since at least 1967. I've had the opportunity of working with the TVA over the last several years, in this area. As far as I'm concerned, the EPA/TVA working relationship should be a guide as to how agencies can work together effectively.

Figure 8 summarizes some of the major TVA contributions in the FGD area. TVA has been a major participant in the Shawee lime and limestone program; they've constructed the facility, and they presently operate the facility. They've participated in the test program formulation. And as I indicated, they are developing a computer program for the generation of design and cost information. This program will put in useful form, all the data we have generated at Shawnee.

They've also operated a 1-megawatt pilot plant under the auspices of the base (non-energy) program at the TVA Colbert power plant facility. The interagency portion of the program started in July of 1975, and it has concentrated on resolving mist eliminator plugging problems. I indicated earlier this plugging problem is probably the most significant of the remaining viability questions for lime and limestone scrubbers. Recent runs have indicated successful mist eliminator performance on both lime and limestone systems.

They are also conducting a program to develop the ammonium bisulfate FGD process. They are about to operate an integrated pilot plant (including the scrubber and regenerator) with sulfuric acid the end product. Although the major outstanding problem is the fume problem--ammonium sulfates create an aesthetic and possibly a health problem which must be solved before this process is considered viable.

TVA efforts also include looking at sulfur product marketing as well as sludge disposal from FGD systems.

As far as I am concerned, the most reliable FGD cost estimates have been generated by TVA. They're looking at many second generation FGD processes this year. I believe that if one is truly interested in representative FGD costs, TVA reports should be reviewed.

Fine Particulate Control

Now, moving away from flue gas desulfurization technology to perhaps a less controversial subject, but quite an important one, nevertheless: fine particulate control.

Fine particulates are an important health hazard (Figure 9) because they are airborne for an extended period of time. Due to their small size, they can penetrate deeply in the lung, and they can act as a transport site for other serious pollutants which can be adsorbed on the surface. A fine particle is defined as being less than two microns in size.

I should point out that there is a direct relationship between fine particulate control and total particulate control. Generally, they are closely related and if one wants to get a reasonable amount of fine particulate removal, you've got to have a very good control of total particulates as well. For example, if one wants 90 percent fine particulate of particles below about two microns, one would probably need on the order of 99 plus percent overall particulate removal for power plant flue gas. So these are not independent parameters; fine partiuclate and particulate control are closely related.

I would like to discuss the make up for our fine particulate program. Figure 10 summarizes the major elements of the program. Measurement techniques are a major problem area. A major goal of this portion of the program is the development of devices capable of continuously and accurately measuring fractional particulate efficiency.

The ESP evaluation program is the second major program element. In this program ESP operation has been characterized for seven particulate sources. Also, a math model has been developed which very accurately describes precipitator operation based on precipitator and particulate parameters. It has been found that these devices have high efficiency for fine particulate control. However, for low sulfur coal combustion, sulfur trioxide levels are low in the flue gas which tends to raise the electrical resistivity of flyash. For this reason, conditioning agents are also being studied in this program. These would be additives which could be added to either fuel or flue gas to try to decrease resistivity; thereby increasing percipitator performance.

The program is also looking at wet scrubbers. As you probably know, scrubbers can be operated to remove either SO_2, particulates, or both. The program has evaluated various devices on a variety of sources. And what we've found is that you can remove fine particulates, if you are willing to pay the penalty of a high pressure drop. You've got to really expend quite a bit of energy into pushing the flue gas through these devices to get reasonably good fine particulate removal.

However, there appears to be an exception to this rule. The turbulent contact absorber (TCA), is a mobile bed type scrubber. For each of the mobile beds, contact is made with scrubbing liquor, with the flue gas through the movement of thin-shelled small spheres. Testing has indicated that uncharacteristically, efficient operation can be obtained in the fine particulate regime without excessive pressure drop. Needless to say, this scrubber type will be evaluated in more detail.

In addition, the force/condensation scrubber has been identified as an attractive scrubber, which could also give reasonably good, fine particulate control without excessive pressure drop.

Fabric filters are also a major element of the program. Thus far, fabric filters have been tested on three different sources and they've been quite efficient of the conventional particulate removal devices. However, there are mechanical and reliability problems which are application dependent and that's where the present R&D program will focus upon.

In addition, we're looking at new ideas and novel devices. To date, nine new concepts have been identified; ten new devices have been tested. We plan to take the best of these and continue testing.

Fluidized Bed Combustion technology, which Dr. Burchard described yesterday, requires a high degree of particulate control for both environmental turbine protection. We're going to initiate a program for developing high temperature and high control technology.

Nitrogen Oxide Control

Now, turning to our NO_x control program. I think a little background might be in order, so I've added some background information (Figure 11). I think there's some history that is relevant. As many of you know, there was an unreliability problem discovered in the ambient air quality measurement technique for NO_2 back in 1972.

Prior to discovery of the problem, it was believed that 47 Air Quality Control Regions (AQCR) out of the total of 247 AQCRs for the country had an NO_2 ambient air problem. What we've found out is that due to an inherent measurement error, ambient levels of NO_2 were measured too high. Using more accurate techniques, only four areas (AQCRs) of the country really seemed to have an NO_2 problem.

However, since 1972, there hasn't been too much progress in NO_2 control from either stationary or mobile sources. As a result, they're now finding new AQCRs exceeding the NO_2 standard and, quite frankly, the trend seems to be for further NO_2 ambient problems. Therefore, our present NO_2 control strategy does not appear very effective. What we have--the present control strategy, basically, includes control of both (automobile) mobile sources as well as stationary sources.

I should point out almost one-half of the emmissions, NO_x emmissions, are from mobile sources; a little more than one-half are associated with stationary sources. So both are of interest if we are to achieve NO_x air quality goals.

We basically have set so-called interim standards for automobiles. This is not a very stringent standard and it's actually less than called the Clean Air Act goal. So, basically, due to economic technology and political considerations, it looks like in the near future, this interim standard will probably suffice.

Also, the new source performance standard (NSPS) philosophy is pased on best available control technology. And for this reason, the NSPS for utility boilers is not a very stringent one, and only requires, as I indicated earlier, on the order of 30 or 35 percent control. There's also a NSPS for nitric acid plants which is also a significant contributor to the NO_xproblem.

So, basically, our present strategy doesn't seem like it's sufficient to get these AQCRs back into line, and for that matter, to turnaround the trend toward additional AQCRs getting out of standard. So, additional control of stationary sources beyond the present level may be necessary.

There are, basically, three major categories of control for NO_x control of stationary sources. The only near-term technology is combustion modification; the present EPA program is primarily focusing on this area. This technology is the basis for the present new source performance standard on large fossile fuel steam generators.

Flue gas cleaning is the second technology. It's similar to flue gas desulfurization; it probably should be called flue gas de-nitrification. We have several embryonic programs in that area which I will briefly describe.

And finally, a very promising technology, fluidized bed combustion, which Dr. Burchard mentioned yesterday. Fluidized Bed Combustion technology will not be discussed here. It is probably ten years away from making a commercial impact, but it's a very promising technology, nevertheless.

The NO_x program does not have a very large inter-agency component. It's primarily EPA directed. Figure 12 summarizes the major elements of this combustion modification program This program aims at developing technology capable of controlling emissions from the two major sources of NO_x from stationary sources; namely, "thermal" NO_x and "fuel" NO_x. One hopes to control "thermal" NO_x by lowering the combustion temperature since the equilibria relationships are such that lower temperatures retards NO_x formulation, i.e., higher temperatures favor the oxidation of nitrogen. And one can control "fuel" NO_x problems by lowering oxygen concentration. Figure 12 delineates the various technologies under development to meet these goals. One might note that, really, the control approaches are generally in common for both thermal and fuel NO_x, with the exception of fluidized bed combustion, which is really oriented primarily toward minimizing thermal NO_x.

One has got to be careful implementing these techniques since it is possible to aggrevate other pollutant emission problems. We could, for example, increase emissions of carbon monoxide or particulate matter, if we drastically lower excess air. We could also, lower thermal efficiency with approaches such as flue gas recirculation. These techniques can also lead to operating problems since boilers will not be operated in some cases under the design conditions that they are designed for.

However, the results of our program today indicate that each of these potential problems are controllable, if one is careful about the particular control technology and the design parameters utilized.

The EPA program in this area basically includes five basic elements which are listed on Figure 12.

Let's turn to the status of the combustion modification program (Figure 13). In terms of the utility industry, the field testing portion of the program is designed to establish emission factors for NO_x and other pollutants associated with utility combustion; this includes oil, gas, and coal-fired utility boilers. For coal-fired boilers, they have determined that 30 or 40 percent NO_x control is feasible for existing units. This approaches new source performance standards. However, some problems have been identified, particularly, boiler tube corrosion and some efficiency losses. Studies are being undertaken to try to resolve these problems.

Industrial and commercial boiler field testing has established reliable emission factors for several types of boilers, for gas, and residual oil-fired applications. It appears to be more difficult to control NO_x in small industrial coal-fired boilers, than the large, more complex utility boilers. However, package gas-fired boilers which have been designed, especially for NO_x control, can achieve 50 and 60 percent removal as compared to residual oil-fired boilers, for example.

Now, for residential furnaces, emission factors have been ascertained and again, it is quite difficult to do much as far as NO_x control is concerned by changing operating conditions on these quite simple burner designs. However, oil-burner developments for residential sources indicate that one can do quite well if one does change the inherent design of the burner itself. For example, 50 to 75 percent NO_x control from gas-fired burners appears feasible by modifying burner types.

In the advanced technology area, fundamental combustion studies are performed, advanced concepts are developed, and burner design modifications are evaluated. One of the results of this program have been the testing of coal-burners which emit only 150 ppm NO_x. One of the advanced concepts that looks attractive is catalytic combustion which can lower combustion temperature and thereby decrease NO_x emissions.

Let me briefly describe the NO_x flue gas treatment R&D program (Figure 14). One might ask in light of the comprehensive combustion modification program I have described--why flue gas treatment? What is the advantage of this technology over combustion modification?

Well, the only identifiable advantage in my mind, is that this technology has the potential for high NO_x removal efficiency. Such systems have demonstrated in excess of 90 percent removal efficiencies in Japan. But, you pay the price for this increased efficiency over combustion modification technology. The systems are complex and costs are quite high. The costs for these systems appear comparable to FGD systems. There are two basic classes of NO_x flue gas cleaning technology-- dry and wet processes. The dry processes involve chemical reduction of NO. A typical reducing agent is ammonia, which can reduce the NO to elemental nitrogen. One has got to select the proper catalysts so we don't reduce SO_x as well, which may be present in the flue gas.

There are several problems that have been identified with this technology in trying to apply this to coal-fired boilers here in the U.S. Primarily, there is uncertainty of the viability of this concept in coal flue gas, since we've got to be concerned about hydrogen chloride, particulates, and other pollutants associated with this gas stream.

Additionally, one has got to be concerned with secondary emissions. For example, ammonium sulfate could be a problem in dry reduction processes when ammonia is used as the chemical reductant.

Also, for the dry systems, you need about 1 mole of ammonia for every mole of NO that's being reduced. This can lead to high reagent costs for control of flue gases with high NO content.

The wet processes, basically oxidizes NO. Typically, they might use ozone as the oxidation agent, and basically try to oxidize NO to NO_2, followed by a scrubbing technique to absorb out the NO_2. This, of course, is a scrubbing system--and does have potential for simultaneous SO_x and NO_x removal. However, problems include using large quantities of ozone as a reagent. As you know, it takes quite a bit of energy to produce ozone. Secondary emissions are a problem, and high costs again, are significant disadvantages.

Our EPA program in this area is really only nominal right now. It is just getting underway. A major element of the program is to determine--is there a need for an FGT program of this type? What should the magnitude of the program be? What should the timeframe of such a program be? The present thrust in this area is related to initiating activities leaning toward eventaul testing of attractive processes at the pilot scale, borrowing very heavily on Japanese technology in this area.

Concluding Paragraph

In conclusion, I've attempted to describe a complex program in the relatively short time period available to me. I hope I've managed to at least describe the essence of the program. I believe the potential impact of our flue gas cleaning program can be substantial, since, generally, the technologies under development/demonstration are near-term technologies which can allow the use of plentiful fossil fuels--particularly high-sulfur coal.

Figure 1

CLEAN AIR ACT DRIVING FORCE FOR FLUE GAS CLEANING

STATUTORY REQUIREMENT TO ACHIEVE ACCEPTABLE AMBIENT AIR QUALITY BY MID 1975 FOR

- SO_2
- NO_2
- TOTAL SUSPENDED PARTICULATES (TSP)
- HYDROCARBONS
- CARBON MONOXIDE
- PHOTOCHEMICAL OXIDANTS

STATUTORY REQUIREMENT TO INSTALL BACT FOR SELECTED NEW SOURCES (NSPS)

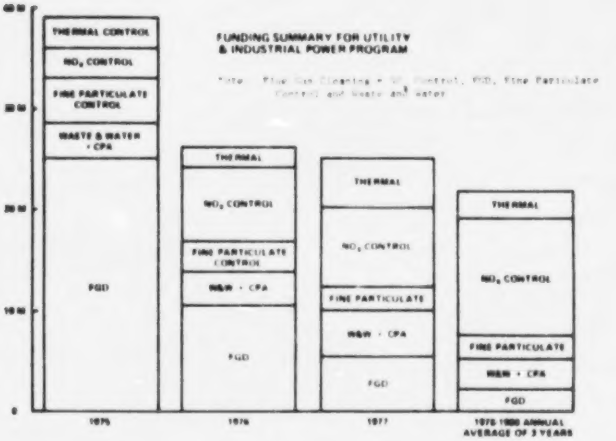
	STANDARD	UNCONTROLLED
SO_2	1.2 lb/10^6 BTU	5 lb/10^6 BTU
TSP	0.1 lb/10^6 BTU	6-10 lb/10^6 BTU
NO_2	0.7 lb/10^6 BTU	2 lb/10^6 BTU

Figure 2

SUMMARY OF CRITICAL PROBLEMS · UTILITY AND INDUSTRIAL CONVENTIONAL COMBUSTION

DESCRIPTION OF PROBLEM	STANDARD PRESENTLY ESTABLISHED	MAGNITUDE OF PROBLEM	TYPE OF FGC CONTROL TECHNOLOGY	PRESENT STATUS	SECONDARY RESIDUALS	NEEDED CONTROL TECHNOLOGY R&D (INCLUDING ASSESSMENTS)	OUTLOOK FOR FUTURE STANDARD
PRIMARY POLLUTANTS SO_2	YES NSPS AND AAQS	MAJOR	COAL CLEANING	1ST GENERATION DEMO PLANNED	HIGH S REFUSE	A) ELIMINATION OF SEC POLLUTANTS B) DEMONSTRATE PRACTICABILITY C) BROADEN APPLICABILITY	POSSIBLE SO_4 STANDARD
			FGD	1ST GENERATION IN FULL SCALE DEMO 2ND GENERATION IN BENCH AND/OR PILOT SCALE	SLUDGE PURGE STREAMS	A) ELIMINATION OF SEC POLLUTANTS B) IMPROVE RELIABILITY C) BROADEN APPLICABILITY D) IMPROVE ENERGY EFFICIENCY	
NO_x	YES NSPS AND AAQS	MAJOR	COMBUSTION MODIFICATION	COMMERCIAL FOR SOME NEW UNITS	POSSIBLY INCREASED PARTIC. AND CO	A) BROADEN SOURCE APPLICABILITY B) IMPROVE ENERGY EFFICIENCY C) IMPROVE NO_x CONTROL EFFICIENCY D) MINIMIZE IMPACT OF RESIDUAL POLLUTION	POSSIBLE NO_3 STANDARD
			FLUE GAS TREATMENT	BENCH AND PILOT SCALE	VARIES WITH PROCESS		
PARTICULATES	YES NSPS AND AAQS	MAJOR	ELECTROSTATIC PRECIPITATORS	COMMERCIAL	FLY ASH	A) IMPROVE COST EFFECTIVE FINE PARTICULATE CONTROL B) BROADEN APPLICABILITY C) DEVELOP NOVEL DEVICES WITH IMPROVED CAPABILITY	POSSIBLE FINE PARTICULATE STANDARD
			BAG HOUSES	PILOT SCALE			
			WET SCRUBBERS	1ST GEN. COMMERCIAL 2ND GEN. FULL SCALE DEMO			
			NOVEL DEVICES	BENCH OR PILOT SCALE			
POTENTIALLY HAZARDOUS MATERIALS	NO	UNDEFINED	UNDEFINED	UNDEFINED	UNDEFINED	PROBLEM REQUIRES DEFINITION	POSSIBLE

Figure 3



FUNDING SUMMARY FOR UTILITY & INDUSTRIAL POWER PROGRAM

*Note: Flue Gas Cleaning = NO_x Control, FGD, Fine Particulate Control and Waste and Water

Figure 4

EPA SPONSORED STACK GAS DESULFURIZATION DEMONSTRATION SYSTEMS

EPA SPONSORED PROCESS (BYPRODUCT)	PARTICIPATING UTILITY	PROCESS DEVELOPER	LOCATION	UNIT SIZE AND TYPE	EXPECTED START UP
NON-REGENERABLE					
LIMESTONE SLURRY SCRUBBING (SLUDGE)	TVA	BECHTEL AND OTHERS	SHAWNEE UNIT 10 PADUCAH KY	10 MW COAL	UNDER WAY
LIME SLURRY SCRUBBING (SLUDGE)	TVA	CHEMICO BECHTEL AND OTHERS	SHAWNEE UNIT 10 PADUCAH KY	10 MW COAL	UNDER WAY
DOUBLE ALKALI SCRUBBING	TO BE SELECTED			> 100 MW COAL	LATE 1976
REGENERABLE					
MAGNESIA SLURRY SCRUBBING REGENERATION (98% SULFURIC ACID)	BOSTON EDISON	CHEMICO BASIC	MYSTIC STATION 6 BOSTON MASS	150 MW OIL	COMPLETED
CATALYTIC OXIDATION (80% SULFURIC ACID)	ILLINOIS POWER	MONSANTO	WOOD RIVER STATION 4 EAST ALTON ILL	110 MW COAL	MID 1974
SODIUM SCRUBBING REGENERATION (SULFUR)	NORTHERN INDIANA PUBLIC SERVICE CO	DAVY POWERGAS ALLIED CHEMICAL	D.H. MITCHELL STATION 11 GARY IND	115 MW COAL	LATE 1975
SECOND GENERATION PROCESS	TO BE SELECTED			> 100 MW COAL	LATE 1976

Figure 5

SUMMARY OF MAJOR NON REGENERABLE FGD R,D & D ACTIVITIES

LIME/LIMESTONE SHAWNEE PROGRAM

- EPA TVA BECHTEL MAJOR PARTICIPANTS
- TWO 10 MWE SCRUBBERS 0.1 MW PILOT SCRUBBER
- OUTPUTS TO DATE
  - RELIABLE OPERATION OF BOTH LIME AND LIMESTONE SYSTEMS DEMONSTRATED
  - DISCOVERY OF UNSATURATED OPERATION
  - ACHIEVED HIGH UTILIZATION
  - EVALUATION OF SLUDGE FIXATION PROCESSES
- PLANNED PROGRAM
  - DETERMINE UPPER LIMITS FOR SO_2 REMOVAL
  - FURTHER EVALUATE UNSATURATED OPERATION
  - GYPSUM PRODUCTION
  - MINIMIZE ENERGY USAGE
  - DEVELOP DESIGN/COST COMPUTER PROGRAM

DOUBLE ALKALI

- EPA BENCH STUDIES
- PILOT STUDIES (ADL)
  - IDENTIFIED RELIABLE, VIABLE OPERATION MODES
  - MINIMIZED SODIUM LOSSES
- PROTOTYPE STUDIES (20 MW SOUTHERN SERVICES/CEA/ADL)
  - RELIABLE, VIABLE OPERATION
- DEMONSTRATION PROGRAM
  - 100 MWE, HIGH SULFUR COAL
  - IN EVALUATION PHASE

LOUISVILLE GAS AND ELECTRIC TEST PROGRAM

- RELIABLE, CHARACTERIZATION TESTS ON HIGH SULFUR 65 MWE UTILITY BOILER
- UNSATURATED OPERATION MODE TO BE EVALUATED
- SLUDGE DISPOSAL STUDIES

Figure 6

SUMMARY OF MAJOR REGENERABLE FGD R,D & D ACTIVITIES

MAGNESIUM OXIDE SCRUBBING

- BOSTON EDISON DEMO
  - 155 MWE OIL FIRED PRODUCES H_2SO_4
  - TEST PROGRAM FROM APRIL 1972 TO JUNE 1974
  - MANY EARLY PROBLEMS OPERABILITY IMPROVED SUBSTANTIALLY
- POTOMAC ELECTRIC TEST PROGRAM
  - 100 MWE COAL FIRED PRODUCES H_2SO_4
  - RESULTS INCONCLUSIVE
- PHILADELPHIA ELECTRIC
  - 120 MWE COAL FIRED
  - POSSIBLE EPA PARTICIPATION

WELLMAN LORD PROCESS

- SUCCESSFUL OPERATION IN JAPAN (ON OIL
- EPA DEMO
  - 115 MWE COAL FIRED NIPSCO PRODUCES SULFUR
  - START UP APRIL 1976

SECOND GENERATION PROCESS

- EPA DEMO PROGRAM
- 100 MWE COAL FIRED PRODUCES SULFUR
- PRESENTLY IN EVALUATION PHASE

OTHER PROGRAMS

- CATALYTIC OXIDATION DEMO
- USBM CITRATE PROCESS DEMO
- TVA AMMONIA SCRUBBING PILOT
- BYPRODUCT MARKETABILITY STUDIES

Figure 7

WASTE AND WATER PROGRAM

FGD SLUDGE DISPOSAL

- SLUDGE IMPROVEMENT STUDIES AT SHAWNEE
- SLUDGE FIXATION PROCESS EVALUATION SHAWNEE AEROSPACE
- SLUDGE DISPOSAL OPTIONS LG & E ADL
- SLUDGE CHARACTERIZATION TVA AND AEROSPACE
- SLUDGE/ENVIRONMENT INTERACTION ARMY SHAWNEE
- DATA BASE FOR DISPOSAL STANDARD (SCS ENG)
- SLUDGE UTILIZATION
  - FERTILIZER PROD TVA
  - $CaSO_3 \rightarrow CaO + S + O_2$ KELLOG
  - GYPSUM MARKET STUDIES TVA

OTHER PROGRAM ELEMENTS

- ASH CHARACTERIZATION AND DISPOSAL (TVA)
- POWER PLANT WATER USE

Figure 8

TVA FGD PROGRAM

TVA A MAJOR PARTNER WITH EPA SINCE 1967

SHAWNEE PROGRAM LIME LIMESTONE SCRUBBING

- CONSTRUCTED AND OPERATED
- MAJOR INPUT INTO TEST PROGRAM AND EVALUATION
- DEVELOPING DESIGN/COST COMPUTER PROGRAM

COLBERT LIMESTONE 1 MWE PILOT PLANT

- STARTED JULY 1975
- EVALUATING MIST ELIMINATORS

AMMONIA 1 MWE PILOT PLANT

- PROMISING PROCESS
- INTEGRATED TESTING PLANNED
- FUME PROBLEM FORMIDABLE

SULFUR SLUDGE/BY PRODUCT PROJECTS

- FERTILIZER FROM SLUDGE
- BYPRODUCT MARKETING
- SLUDGE CHARACTERIZATION

FGD ECONOMIC STUDIES

- LIME, LIMESTONE MAG OX W L CAT OX D/A CITRATE
- OTHER REGENERABLE PROCESSES

Figure 9

FINE PARTICULATE CONTROL PROGRAM BACKGROUND

FINE PARTICULATES ARE HEALTH HAZARDS BECAUSE:

- AIRBORNE FOR EXTENDED TIME PERIODS
- PENETRATE DEEPLY IN LUNG
- ACT AS TRANSPORT AGENTS FOR OTHER POLLUTANTS

EPA R,D & D PROGRAM INCLUDES

- MEASUREMENT TECHNIQUE DEVELOPMENT
- IMPROVEMENT AND CHARACTERIZATION OF PRESENT TECHNOLOGY
  - ESPs
  - SCRUBBERS
  - FABRIC FILTERS
- NEW IDEAS/NOVEL DEVICES
- HIGH TEMP /HIGH PRESSURE CT

Figure 10

FINE PARTICULATE PROGRAM

MEASUREMENT TECHNIQUE DEVELOPMENT

- GOAL IS TO PRODUCE DEVICE WHICH IS CONTINUOUS AND ACCURATELY MEASURES FRACTIONAL EFFICIENCY

ESP PROGRAM

- CHARACTERIZATION FOR SEVEN SOURCES
- MATH MODEL IS DEVELOPED
- CAPABLE OF HIGH EFFICIENCY IF NO RESISTIVITY PROBLEM
- CONDITIONING BEING EVALUATED

SCRUBBERS

- EIGHT DEVICES TESTED ON A VARIETY OF SOURCES
- PERFORMANCE DEPENDENT ON PRESSURE DROP
- TCA SCRUBBER UNCHARACTERISTICALLY EFFICIENT
- FORCE CONDENSATION SCRUBBERS UNDER DEVELOPMENT

FABRIC FILTERS

- TESTING FOR THREE SOURCES COMPLETED
- EFFICIENT DOWN TO 0.3
- PROGRAM AIMED AT INCREASING APPLICABILITY AND OPERABILITY

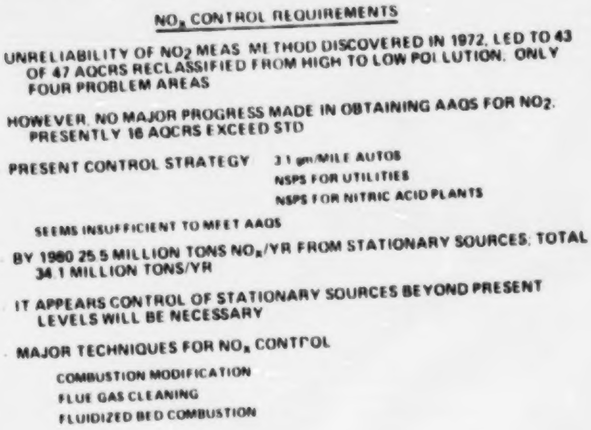
NEW IDEAS/NOVEL DEVICES

- 40 NEW CONCEPTS EVALUATED 9 APPEAR PROMISING
- 30 NEW DEVICES EVALUATED 10 APPEAR PROMISING

HIGH TEMP /HIGH PRESSURE CT

- FBC AND LOW BTU GASIFICATION NEED CT
- PROGRAM AIMED AT DEFINING REQUIREMENTS AND EVALUATING CONCEPTS AND DEVICES

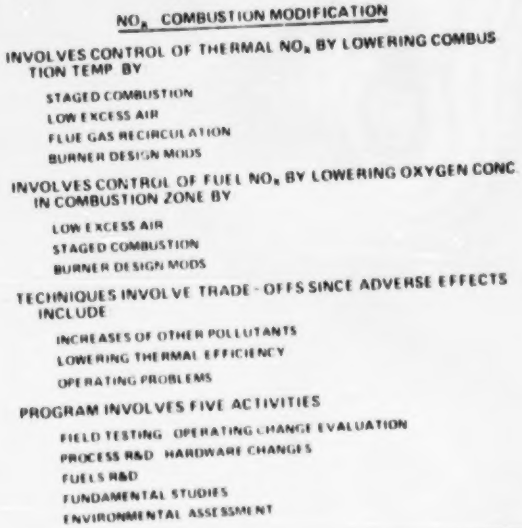
Figure 11



NO$_x$ CONTROL REQUIREMENTS

- UNRELIABILITY OF NO_2 MEAS. METHOD DISCOVERED IN 1972, LED TO 43 OF 47 AQCRS RECLASSIFIED FROM HIGH TO LOW POLLUTION. ONLY FOUR PROBLEM AREAS
- HOWEVER, NO MAJOR PROGRESS MADE IN OBTAINING AAQS FOR NO_2. PRESENTLY 16 AQCRS EXCEED STD
- PRESENT CONTROL STRATEGY
  - 3.1 gm/MILE AUTOS
  - NSPS FOR UTILITIES
  - NSPS FOR NITRIC ACID PLANTS
  - SEEMS INSUFFICIENT TO MEET AAQS
- BY 1980 25.5 MILLION TONS NO$_x$/YR FROM STATIONARY SOURCES; TOTAL 34.1 MILLION TONS/YR
- IT APPEARS CONTROL OF STATIONARY SOURCES BEYOND PRESENT LEVELS WILL BE NECESSARY
- MAJOR TECHNIQUES FOR NO$_x$ CONTROL
  - COMBUSTION MODIFICATION
  - FLUE GAS CLEANING
  - FLUIDIZED BED COMBUSTION

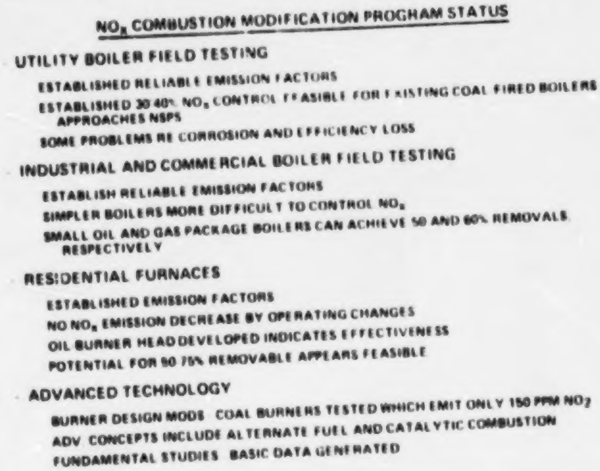
Figure 12



NO$_x$ COMBUSTION MODIFICATION

- INVOLVES CONTROL OF THERMAL NO$_x$ BY LOWERING COMBUSTION TEMP. BY
  - STAGED COMBUSTION
  - LOW EXCESS AIR
  - FLUE GAS RECIRCULATION
  - BURNER DESIGN MODS
- INVOLVES CONTROL OF FUEL NO$_x$ BY LOWERING OXYGEN CONC. IN COMBUSTION ZONE BY
  - LOW EXCESS AIR
  - STAGED COMBUSTION
  - BURNER DESIGN MODS
- TECHNIQUES INVOLVE TRADE-OFFS SINCE ADVERSE EFFECTS INCLUDE
  - INCREASES OF OTHER POLLUTANTS
  - LOWERING THERMAL EFFICIENCY
  - OPERATING PROBLEMS
- PROGRAM INVOLVES FIVE ACTIVITIES
  - FIELD TESTING: OPERATING CHANGE EVALUATION
  - PROCESS R&D: HARDWARE CHANGES
  - FUELS R&D
  - FUNDAMENTAL STUDIES
  - ENVIRONMENTAL ASSESSMENT

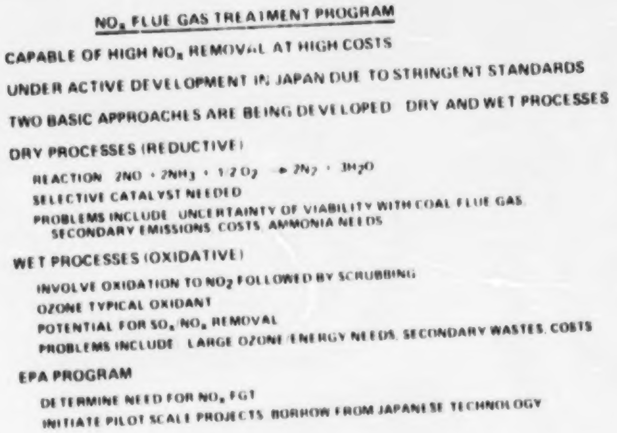
Figure 13



NO$_x$ COMBUSTION MODIFICATION PROGRAM STATUS

- UTILITY BOILER FIELD TESTING
  - ESTABLISHED RELIABLE EMISSION FACTORS
  - ESTABLISHED 30-40% NO$_x$ CONTROL FEASIBLE FOR EXISTING COAL FIRED BOILERS APPROACHES NSPS
  - SOME PROBLEMS RE CORROSION AND EFFICIENCY LOSS
- INDUSTRIAL AND COMMERCIAL BOILER FIELD TESTING
  - ESTABLISH RELIABLE EMISSION FACTORS
  - SIMPLER BOILERS MORE DIFFICULT TO CONTROL NO$_x$
  - SMALL OIL AND GAS PACKAGE BOILERS CAN ACHIEVE 50 AND 60% REMOVALS RESPECTIVELY
- RESIDENTIAL FURNACES
  - ESTABLISHED EMISSION FACTORS
  - NO NO$_x$ EMISSION DECREASE BY OPERATING CHANGES
  - OIL BURNER HEAD DEVELOPED INDICATES EFFECTIVENESS
  - POTENTIAL FOR 50-75% REMOVABLE APPEARS FEASIBLE
- ADVANCED TECHNOLOGY
  - BURNER DESIGN MODS: COAL BURNERS TESTED WHICH EMIT ONLY 150 PPM NO_2
  - ADV. CONCEPTS INCLUDE ALTERNATE FUEL AND CATALYTIC COMBUSTION
  - FUNDAMENTAL STUDIES: BASIC DATA GENERATED

Figure 14



NO$_x$ FLUE GAS TREATMENT PROGRAM

- CAPABLE OF HIGH NO$_x$ REMOVAL AT HIGH COSTS
- UNDER ACTIVE DEVELOPMENT IN JAPAN DUE TO STRINGENT STANDARDS
- TWO BASIC APPROACHES ARE BEING DEVELOPED: DRY AND WET PROCESSES
- DRY PROCESSES (REDUCTIVE)
  - REACTION: $2NO + 2NH_3 + 1/2\,O_2 \rightarrow 2N_2 + 3H_2O$
  - SELECTIVE CATALYST NEEDED
  - PROBLEMS INCLUDE: UNCERTAINTY OF VIABILITY WITH COAL FLUE GAS, SECONDARY EMISSIONS, COSTS, AMMONIA NEEDS
- WET PROCESSES (OXIDATIVE)
  - INVOLVE OXIDATION TO NO_2 FOLLOWED BY SCRUBBING
  - OZONE TYPICAL OXIDANT
  - POTENTIAL FOR SO$_x$/NO$_x$ REMOVAL
  - PROBLEMS INCLUDE: LARGE OZONE/ENERGY NEEDS, SECONDARY WASTES, COSTS
- EPA PROGRAM
  - DETERMINE NEED FOR NO$_x$ FGT
  - INITIATE PILOT SCALE PROJECTS: BORROW FROM JAPANESE TECHNOLOGY

FLUE GAS DESULFURIZATION

H. W. Elder
Office of Agricultural and Chemical Development
Tennessee Valley Authority
Muscle Shoals, Alabama

G. A. Hollinden
Office of Power
Tennessee Valley Authority
Chattanooga, Tennessee

INTRODUCTION

A Federal interagency working group was assembled by OMB in 1974 to develop a research and development plan for environmental control technology to meet the needs of a variety of energy systems. TVA representatives participated intensively in the planning that led to definition of a program. This resulted in identification of specific projects for performance by TVA in the area of flue gas desulfurization; most of the projects were ongoing studies funded through separate interagency agreements between EPA and TVA. A new agreement was executed to define the basis for performance of work with funds provided by EPA on a pass-through basis to TVA. The objectives, plans, and funding levels for specific projects are specified in subagreements prepared jointly by TVA and EPA. The current program related to flue gas desulfurization includes pilot-plant and prototype-scale testing of lime and limestone scrubbing, evaluation of sludge disposal, bench- and pilot-scale studies of recovery of SO_2 in useful form, evaluation of market potential for sulfur by-products, and technical and economic evaluation of alternative processes.

PROTOTYPE-SCALE EVALUATION OF LIME AND LIMESTONE SCRUBBING--SHAWNEE TEST FACILITY

Purpose and Scope

The purpose of this program that began as a cooperative study by EPA, TVA, and Bechtel Corporation in 1970 is to fully characterize lime and limestone scrubbing processes and to evaluate waste disposal. TVA has the responsibility for operating and maintaining the test facility and for providing quality data for evaluation by Bechtel. Support activities include design and installation of process or plant modifications, equipment inspection and evaluation of materials, sampling and analysis of leachate and ground water in conjunction with storage tests of treated and untreated sludge, and economic evaluations. A complex computer program is being developed to incorporate process, design, and operating parameters in a model to predict economic trade offs. TVA contributes to planning of the program and evaluation of results through membership in a steering committee that directs the program.

Project Status

Three different 10-MW scrubbing systems were constructed and operation began in early 1972. Short-term factorial tests were run with limestone in all three systems to determine the effect of variables on SO_2 removal efficiencies. Subsequently, one system was shut down because of operational problems and the other two have recently been operated on longer term, closed-loop tests, one with limestone and one with lime. Much has been learned about the chemistry and performance of the systems; reliability has been greatly improved through process and mechanical modifications. Future tests will focus on improved limestone utilization, oxidation of sludge, and further evaluation of system reliability with and without fly ash in the scrubber.

Tests of waste disposal are in progress. Separate clay-lined ponds have been filled with untreated lime and limestone sludge and with sludge stabilized by three different methods. Core samples of the solids are collected periodically for physical and chemical tests and both leachate and ground water quality are monitored. Additional storage tests are planned with oxidized sludge; this material should have improved physical properties compared to the normal sulfite type.

All of the data have been assembled for the basic computer economic model and the program should be ready for use by March 1976. Additional work is planned to incorporate subroutines for particulate removal, sludge disposal, and other factors that will make the results more meaningful.

References

1. Bechtel Corporation. "EPA Alkali Scrubbing Test Facility: Summary of Testing through October 1974," EPA Report 650/2-75-047, June 1975.

2. Epstein, Michael. "EPA Alkali Scrubbing Test Facility: Advanced Program," First Progress Report, Bechtel Corporation, San Francisco, California. EPA Report 600/2-75-050, September 1975.

LIME/LIMESTONE 1-MW PILOT PLANT

Purpose and Scope

The objectives of this study are to determine the effects of gas velocity and solid/liquid loadings on mist eliminator performance and to determine the mechanical and chemical methods necessary to maintain continuous reliable mist eliminator performance for horizontal and vertical mist eliminators.

Project Status

Operation of the 1-MW pilot plant began in July

1975 using a venturi prewash section followed by a TCA absorber. The venturi section operated with a liquid-to-gas ratio (L/G) of 10 and at 9 inches pressure drop. The TCA was operated at a superficial gas velocity of 12.6 feet per second, and a L/G of 50 using two stages (each 7 inches deep) of mobile packing spheres with a pressure drop (total) of 6 inches. The mist eliminator tested was a three-pass, 90-degree bend chevron located in the horizontal position in the vertical absorber tower.

In the limestone mode, soft mud-like solid deposits occurred in the first pass of the chevron while using all the allowable fresh water for washing. The results of these initial tests emphasized the need for frequent intermittent front wash. The back two passes which were also intermittently washed, but less frequently with fresh water, remained clean. Modified front face washing using all the available clarified liquor, immediately followed by fresh water on an intermittent basis, allowed continuous operation for 1000 hours.

In the lime mode, continuous operation for 500 hours was possible using the allowable fresh water on an intermittent basis. No clarified liquor wash was necessary.

It was quite difficult even in this small pilot plant to keep the mist eliminators clean while employing only the available liquor allowed for closed-loop operation. It is extremely important that adequate liquor coverage to the mist eliminator be maintained. Such coverage requires consistent spray patterns since over coverage is not possible due to the restrictions in liquor availability. The results completed to date in this study are encouraging, but point out the sensitivity in controlling mist eliminator deposits even in small-scale equipment. Future plans are to operate the chevron-type mist eliminator in the vertical position in the horizontal duct at somewhat higher gas velocities (greater than 12.5 ft/s). Both the lime and limestone modes will be tested. If time permits, the mist eliminator will be repositioned in the vertical duct and operated at higher gas velocities (greater than or equal to 16 ft/s).

Reference

1. Schultz, J. J., et al. "Performance of Entrainment Separators in Slurry Scrubbing Processes," Bulletin Y-93, Tennessee Valley Authority, Muscle Shoals, Alabama, June 1975.

WASTE SOLIDS CHARACTERIZATION AND TREATMENT

Purpose and Scope

This research project should provide the following studies and evaluations directed toward the disposal or utilization of sludge produced by throwaway desulfurization processes: (1) a technical, economic, and environmental impact evaluation for the production of granular fertilizer from scrubber product sludge, (2) a study to determine the range of variability of the solids produced from the scrubbers operated at the Shawnee test facility and a correlation of this variability with plant and scrubber operating conditions, and (3) a study to characterize fluidized bed combustion waste products and to evaluate treatment for both disposal and regeneration.

Project Status

A production run was initiated to produce 10 to 15 tons of a 5-20-0 6S fertilizer but was not successful. The problem area was with the preneutralizer. Here, severe foaming occurred, SO_2 was evolved, and frequent plugging occurred in the slurry pump and pipe system going from the preneutralizer. Overwetting in the granulator also created problems in pilot-plant production. An evaluation of these problem areas has been made. Characterization of sludge and dried solids has been under way for 6 months although only recently have samples been received on a regular basis. The sparseness of data collected does not provide a sound enough base to permit statistical analysis to obtain a correlation. A current state of the art has been compiled concerning the status of fluidized bed combustion processes (FBC) and methods of disposal or regenerating spent bed sorbent material. Organizations involved in the development of FBC processes are being contacted so as to obtain waste material for characterization.

Testing and development of the preneutralization step will be carried out independent of the fertilizer pilot plant. After the feasibility of this step has been established, more pilot-plant testing will be made. Characterization of sludges from the Shawnee plant will continue. Statistical analysis will be made to determine a correlation with plant operation. This will be a 2-year program. Waste products from four or five FBC processes will be characterized both chemically and physically. Disposal methods for this waste material will be studied (2-year program).

ADVANCED CONCEPTS SO_2 REMOVAL PROCESS IMPROVEMENTS--BENCH-SCALE STUDIES

Purpose and Scope

The project provides bench-scale laboratory investigation of promising concepts for improving SO_2 removal and recovery processes. Various systems for removing SO_2 from stack gas streams will receive attention with major emphasis on a potassium system which is not being studied elsewhere. One mode of operation under development is a highly energy efficient potassium system which provides for crystallization of a salt containing recovered SO_2 during scrubbing, separation from the scrubbing liquor, and heating the salt to drive off one-third of the SO_2, converting the remaining two-thirds to hydrogen sulfide, and reacting the SO_2 and hydrogen sulfide to form elemental sulfur. In some other scrubbing systems such as ammonia and lime or limestone slurry, oxidation of the SO_2 to sulfate form may be desirable; small-scale studies of oxidation methods and devices will be made.

Project Status

Major problems in utilizing potassium scrubbing to produce elemental sulfur or sulfuric acid are oxidation during scrubbing and disproportionation of SO_2 to other forms during heating; these problems limit the amount of SO_2 per unit of absorbent that can be driven off. Studies of the scrubbing step show that the system is highly efficient for removing SO_2 from stack gas but the effects of variables on oxidation were not very reproducible; efforts are being made to develop better techniques for studying oxidation. Other test results show that the presence of a small amount of phosphate during heating will control disproportionation enough to allow the desired amount of SO_2 to be driven off; therefore, further research efforts will be directed mainly toward other steps of the process. Exploratory work on conversion of recovered SO_2 to hydrogen sulfide is being initiated. By January 1976, it is expected that potassium scrubbing techniques will be developed to the extent that results on oxidation during scrubbing will be reproducible and studies of the effects of variables will be in progress. Initial results on production of hydrogen sulfide should be available and further work is planned; reaction of SO_2 and hydrogen sulfide to form elemental sulfur is commercially proven and will require no further development. Work will be started on oxidation of recovered SO_2 to sulfate form as soon as the equipment is assembled early next year.

AMMONIA BISULFATE PILOT PLANT

Purpose and Scope

The advanced-concepts (ABS) pilot-plant program is the evolutionary result of an interagency agreement between TVA and EPA. In 1968, EPA commissioned TVA to develop an ammonia absorption process to remove SO_2 from coal-fired power plant stack gases. Ammonia is widely available, relatively low in cost, easy to handle, and has a high affinity for SO_2. Early research and development efforts proved the effectiveness of ammonia absorption. The reaction products of ammonia absorption (soluble ammonia salts) can be regenerated to recover the SO_2 which can be further processed to sulfuric acid or elemental sulfur. Secondary byproducts of the regeneration section are gaseous ammonia and crystalline ammonium sulfate. The sulfate is thermally decomposed to the acid ammonium bisulfate which is used to recover the SO_2 from the absorber product liquor. During the decomposition, gaseous ammonia is evolved and is returned to the absorber loop. To the extent that oxidation occurs in the system, surplus ammonium sulfate is produced. The ammonium sulfate can be used as a fertilizer. The basic purpose of the advanced-concepts test program is to develop and demonstrate the technology of this closed-loop regenerable process.

Project Status

All the equipment needed for the closed-loop process has been purchased and is onsite except for the ammonium sulfate decomposer. All parts of the plant have been tested with reasonable success. The absorption step has been studied extensively and good SO_2 and ammonia recovery have been achieved. Crystal production and separation have been tested. There are a few remaining problems associated with the system; the most serious is the formation of a dense blue-white fume made up largely of ammoniacal salts. The fume is formed in the absorber, then passes through the absorber to persist as a plume from the plant stack. Tests are being run to determine the operating conditions necessary to prevent the formation of this plume. The contract for the construction of the ammonium sulfate decomposer has been awarded and the expected delivery date is April 1976. Preparations are under way for installation of the decomposer. Long-term tests have been deferred until the system can be fully integrated. Bench-scale thermal decomposition tests are being run to define operating parameters and to determine the amount of ammonia cracking that may occur in the vessel.

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BYPRODUCT MARKETING

Purpose and Scope

The initial objectives of this program were directed toward an assessment of the market potential for byproduct abatement sulfuric acid and elemental sulfur from power plants in the eastern United States. A system approach using inputs from several data bases combined in a complex computer model is being developed. As the data bases from the various sources were acquired, verified, adapted, and cataloged, it became apparent that sufficient information was available to assess all power plant and acid plant candidates in the United States. Furthermore the influence of smelters and sour gas sulfur sources became so important that they could not be realistically ignored. The need for increasing the accuracy of the cost screen for flue gas desulfurization systems by use of a retrofit difficulty factor also became apparent. The complexity of the model was such that additional refinement to reduce computer cost appeared desirable. The acid plant production cost inputs and elemental sulfur transportation rates need to be updated to provide a common cost base for all inputs in the model. Because of these factors, it was decided by TVA and EPA that an interim report describing the progress to date, design of the systems analysis model, and the possible uses would be prepared. A final report will be prepared covering a complete market assessment of abatement sulfur and acid from all major sources for the entire continental United States upon completion of the expanded phase of the project. As part of this series, future studies planned include assessment of potential for other abatement byproducts such as gypsum for wallboard, ammonium sulfate, sodium sulfate, and related fertilizer materials. These studies would utilize the computer model developed.

Project Status

A systems analysis model has been developed and tested on the eastern U.S. market. A draft interim report has been prepared and presented to EPA entitled "The Potential Abatement Production and Marketing of Byproduct Elemental Sulfur and Sulfuric Acid in the United States." In the near-term future, major emphasis will be placed on refining and verifying the existing data bases which support the systems analysis approach for evaluating potential byproduct marketing of abatement sulfur and acid in the 48 contiguous states of the United States. The data bases and the model will be available on a time-sharing network which will allow access to any private or public agency interested in abatement byproduct marketing.

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COMPARATIVE ECONOMICS OF MAJOR PROCESSES BEING DEVELOPED FOR REMOVAL OF SO_2 FROM POWER PLANT STACK GASES

Purpose and Scope

For the past several years additional SO_2 removal processes have progressed through research and development toward viable alternatives for desulfurization of power plant stack gases. These processes are in various stages of development in laboratory-, pilot plant-, and demonstration-scale installations. The primary purpose of this study is to review these processes and their development; then, systematically select and evaluate those which have the greatest degree of development and which are potentially attractive both technically and economically. These evaluations include preparation of flowsheets, material balance, and commercial layouts; definition of process equipment; estimation of process equipment costs; preparation of capital investments and operating costs; and analysis of design and economic variables for cost sensitivity. Comparative technology analyses and preliminary economic estimates will also be prepared, as requested by EPA, for an SO_2 removal process of the regenerable, sulfur-producing type for demonstration-scale testing on a 100-MW electric power unit and an SO_2 removal process of the double-alkali type for a similar demonstration-scale installation. As part of the overall EPA sludge disposal program, a portion of this project will provide a design and cost study of the numerous lime-limestone scrubbing sludge disposal alternatives. The economic and technical premises for these comparisons will be established and surveys of cost studies and cost data for operating and planned commercial units will be made.

Project Status

Thus far, the principal activities in the study include the preparation of technical critiques and comparative economics on candidate SO_2 removal processes for demonstration-scale testing on a 100-MW electric power unit, providing related-support analysis for EPA in their selection of processes, and gathering data and information toward completion of the primary purpose of this study. In addition to extensive literature surveys having been made, the offices and/or installations of process vendors for potential processes have been visited to obtain primary-source information and data. By the end of January 1976, both a detailed economic study of the U.S. Bureau of Mines citrate process and the lime-limestone scrubbing sludge disposal study will have begun. As soon as the process selections for the EPA 100-MW demonstration-scale installations are made, detailed economic studies of two additional processes, one from the regenerable, sulfur-producing group and one from the double-alkali group, will commence.

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All the above reports were prepared for EPA.

ENERGY REQUIREMENT CONSERVATION--STUDY OF SELECTED PROCESSES FOR REMOVING SO_2 FROM POWER PLANT STACK GASES

Purpose and Scope

One of the objectives of this study project is to summarize the energy requirements of selected power plant stack gas SO_2 removal processes. Conceptual design and cost studies will be surveyed for energy requirement data. Also a survey will be made of the energy requirement data for any existing demonstration and commercial units. The data obtained from these surveys will be summarized and analyzed to establish a current base energy requirement level for each of the processes. Feasibility and economic evaluations will then be made of process modifications and variations for reducing and optimizing the energy requirements. Process modifications and variations to be studied will include such items as scrubber type, reheat level and type, heat recovery systems, etc.

Project Status

Preliminary discussions have been held between the TVA project director and the EPA project officer covering the approach, scope, premises, etc., for the project. Subsequently, EPA and TVA agreed to revise the schedule in conjunction with the schedule for the cost study project on sludge disposal for lime and limestone SO_2 removal processes to be done by TVA under the same TVA-EPA contract. In essence the two projects will be done sequentially rather than concurrently as previously planned with the sludge disposal cost study project being done first. The advantages for these revisions in the schedules of the two projects are (1) each project will be done over a shorter time period resulting in improved efficiency and simplification of reporting; (2) this will permit utilization of the Shawnee economic computer program, currently being developed on a separate project for lime and limestone scrubbing processes, on the energy optimization study project; and (3) the sludge disposal cost study will be completed at a much earlier date. EPA has concurred with this change in the project schedules. With the above changes further work on the project will be delayed until the second quarter of FY 1976.

FUNDING LEVEL ($M)

	FY 1975	FY 1976
Prototype	3,069	2,950
Lime/limestone pilot plant	600	0
Waste solids	200	150
Bench scale	281	100
ABS pilot plant	2,000	0
Byproduct marketing	350	300
Comparative economics	300	350
Energy conservation	50	50

REGENERABLE FLUE GAS DESULFURIZATION TECHNOLOGY FOR STATIONARY COMBUSTION SOURCES

Richard D. Stern
U.S. Environmental Protection Agency
Industrial Environmental Research Laboratory
Research Triangle Park, North Carolina

INTRODUCTION

In the mid-1960's, EPA instituted a program for the research, development, and demonstration of flue gas desulfurization (FGD) technology. An initial emphasis of the program was the development of SO_2 scrubbing systems using lime or limestone slurries to absorb SO_2 from flue gases forming calcium sulfite and calcium sulfate solids. Concurrently, the Agency recognized the advantages of FGD systems in which the sorbent is regenerated and reused, and investigative activities were initiated in this area. In addition to providing significant SO_2 control capability, regenerable FGD processes, which do not generate throwaway sludge, conserve natural resources of land and sulfur, and produce a by-product with market and social value. By July 1973, interest in and commitments to regenerable FGD process development had grown to the extent that the Industrial Environmental Research Laboratory (IERL) formed a separate Branch with responsibility for the development of the technology. This paper addresses the EPA program for regenerable FGD and the status of this technology.

TECHNICAL DISCUSSION

Flue gas desulfurization is considered the major sulfur oxides control technique that will have widespread application to large coal-fired combustion sources within the next 10-15 years. The basis for this is the current and projected shortage of clean fuels, increasing use of coal for power production, and the early state of development and projected economic/energy penalties associated with alternate control approaches such as coal gasification and liquefaction. The growing awareness that widespread use of FGD will be necessary to maintain acceptable air quality levels has resulted in increased interest in and acceptance of FGD processes in general and regenerable FGD processes in particular. A carefully planned, coordinated, and phased developmental program producing relevant results is being maintained to assist and support the projected growth of FGD technology over the next decade. The overall program comprises laboratory investigations, bench and pilot scale developmental evaluation, and prototype/full-scale demonstrations. These efforts are supported by technical evaluation studies, cost studies, monitoring and analyses, and other related work as necessary. Such a program provides the foundation from which utilities and others can implement the technology at reasonable costs and with reasonable assurance of success in meeting the requirements of the Clean Air Act.

PROGRAM DISCUSSION

EPA has advanced the development of regenerable FGD technology through a multi-faceted program coordinated through IERL at RTP. Begun in 1968, the program consists primarily of EPA/Industry contract activities, and interagency agreements with TVA and the USBM. Significant programs/processes supported by the EPA research, development, and demonstration effort are listed below:

1. EPA/Industry Contract Activity

Magnesium Oxide Scrubbing - EPA co-funded the first U.S. demonstration and testing of the Mag-Ox Process at Boston Edison's 155 Mw oil-fired Mystic Station. Boston Edison provided capital for the scrubbing facility, EPA paid for the regeneration system and acid plant maintenance, and also funded the test program. Although the system operated intermittently during 1972 and 1973, operation during the last six months of the test program showed greatly improved availability. The facility was shut down as scheduled at the conclusion of the test program in June 1974. Utility representatives stated that the demonstration at Mystic Station indicated that a full-station (1050 Mw) Mag-Ox system could be built and operated with high probability of success.

Construction of a 100 Mw Mag-Ox system was completed at Potomac Electric Power Company's (PEPCo) coal-fired Dickerson Station in August 1973. EPA maintained the regeneration and acid production facility to support process evaluation and co-funded the test program. Although the FGD unit only operated intermittently until its service as an SO_2 scrubber was terminated in September 1975, particulate and SO_2 removal efficiency guarantees were corroborated during operational phases. The utility is evaluating its compliance options and has indicated that, based on program results, they would consider application of this process.

A third full-scale (120 Mw) Mag-Ox facility was undergoing start-up in late 1975 at Philadelphia Electric Company's (PE) coal-fired Eddystone Station. System operation is temporarily suspended pending arrangements for the regeneration and acid production facility. EPA and PE are discussing a joint comprehensive test program. PE has indicated its willingness to install an additional 728 Mw of Mag-Ox capacity pending results of this program.

Wellman-Lord Process - EPA is co-funding the first U.S. utility application of this process on a 115 Mw coal-fired boiler at Northern Indiana Public Service Company's (NIPSCo) Mitchell Station. In addition, EPA is funding a comprehensive test and evaluation program. The installation, scheduled for start-up in April 1976, is the first coal-fired application of this technology in the world. The overall system, which incorporates the Allied SO_2 Reduction Process, is also the first commercial scale FGD system to produce elemental sulfur.

The Wellman-Lord Process has logged many years of highly reliable operating experience on various applications including oil-fired boilers in Japan. Approximately ten additional Japanese units are in design or construction phases. The Allied Process has been demonstrated on a large scale, treating a 12% SO_2 gas stream from a nickel ore roaster in Ontario.

At its coal-fired San Juan Station, Public Service Company of New Mexico will soon initiate construction of two Wellman-Lord/Allied FGD installations totaling 715 Mw and is planning the installation of the Wellman-Lord technology on two additional units totaling 1000 Mw.

Catalytic Oxidation - Construction of the EPA/Illinois Power (IP) co-funded 110 Mw Cat-Ox demonstration facility was completed in 1972 at IP's coal-fired Wood River Station. Under EPA sponsorship, baseline testing, precipitator performance, and process acceptance testing were completed. Long term operation has been precluded by a lack of natural gas to fire the reheat burners, the requirement to convert the reheat burners to oil-firing, and continuing acid leakage problems in the product acid coolers. System restart and initiation of the test program await a decision concerning the cost and schedule impact of necessary repair and refurbishment, test program costs, and potential benefits. Although the process cannot be considered commercially demonstrated at this time, successful operation of a 15 Mw prototype from 1967 through 1969 indicates the basic viability of the process.

Alternate Reductant Gases - The shortage of natural gas makes it imperative to seek other sources of reductant gases for the production of elemental sulfur in a number of regenerable FGD processes. EPA has a program to study and evaluate processes and equipment for economical generation of such gases from sources such as coal, coke, and heavy oil. Pending results of the study, experimental work will be conducted on gasification processes for application to selected FGD systems.

Advanced Regenerable Demonstration - EPA is currently negotiating for the full-scale demonstration of an advanced regenerable process which utilizes an alternate reductant and produces elemental sulfur as the by-product. Capitalization would be on a cost-sharing basis with the host utility and EPA would fund a one-year test program.

2. Interagency Agreement Activity

In addition to the significant EPA/Industry contract activities cited above, EPA is also seeking to further the development and demonstration of regenerable FGD processes through coordinated interagency agreements with TVA and USBM. Current interagency agreements contributing to regenerable FGD process development include the following:

TVA - Ammonia Scrubbing/Ammonium Bisulfate Regeneration Process - EPA/TVA have been working together since 1972 to develop a cyclic process that produces a concentrated stream of SO_2 which can be converted to sulfuric acid or elemental sulfur. A 1 Mw pilot facility is operated by TVA at the Colbert Power Station near Muscle Shoals, Alabama.

TVA - By-Product Marketability - EPA/TVA are continuing studies of the economics of marketing sulfuric acid and elemental sulfur produced by regenerable FGD systems at coal-fired power plants in the U.S. The study considers SO_2 emissions compliance requirements and will identify optimum acid and sulfur production and distribution patterns. A portion of the overall study is to evaluate the utilization and marketing of gypsum, a potential by-product of sludge producing systems.

TVA - Economics of Regenerable FGD Processes - EPA/TVA are continuing economic studies and comparisons of both regenerable and non-regenerable FGD processes including sludge handling and disposal. Such studies are essential since the viability of a given FGD process relates directly to its capital and operating costs.

TVA - Energy Conservation in FGD Processes - This study is directed toward identifying possible reductions in electrical and chemical energy requirements of FGD processes. Methods, techniques, design changes, operating changes, and other means of reducing energy usage by FGD processes are being explored.

USBM - Citrate Process - EPA and the USBM have pooled funds and technical talents to demonstrate the Citrate Process at a full-scale, coal-fired site. Negotiations are currently underway with prospective host sites and process vendors.

As stated earlier, these contract and interagency programs are supplemented by a number of small study contracts either directly related to specific projects or of a general nature. These latter studies may be to extrapolate results to other utility type applications, for general strategy/technology assessments related to these and other applications, or for engineering applications/information transfer of the technology.

PROJECTION

The regenerable FGD work has focused primarily on accelerating commercialization of processes through development and large scale co-funded demonstration programs. As a result of the availability of a FGD process "shopping list" and the growing acceptance and commitment of FGD for regulatory compliance, this basic approach is becoming much more selective. Advanced processes must now compete technically and economically with current systems. Performance must be more cost-effective; the process should offer greater reliability and require less energy. Within this framework regenerable FGD activities will focus on: (1) completing on-going and planned demonstration programs that have been funded; (2) performing studies and evaluations related to extending process applicability and improving process costs, reliability, and performance; and (3) developing and demonstrating advanced processes that offer significant advantages over current systems. These advantages may be in lower cost, higher performance, improved operability and reliability, lower energy requirement, and multi-pollutant control potential such as simultaneous SO_x/NO_x emissions control.

This change in emphasis is accompanied by generally lower funding levels as discussed below.

RESOURCE ALLOCATION

Since 1970, regenerable FGD has been a major component of EPA's program to develop SO_2 control technology for stationary combustion sources. The EPA base program was augmented by energy supplement funds in FY-74 and subsequent years. This substantial funding enabled ongoing demonstration programs to be accelerated and allowed initiation of major new demonstration programs and important supporting work. Total resource allocations since FY-74 and projected through the current year are shown in the following table. Funds are $\$ \times 10^6$ and include interagency programs.

FY-74		FY-75		FY-76
Base	Energy	Base	Energy	
1.3	2.9	0.4	11.3	4.2

In FY-74 and -75, the Magnesium Oxide, Wellman-Lord, and Catalytic Oxidation programs received supplemental funding, and an advanced regenerable process using an alternate reductant to produce by-product elemental sulfur was funded. In addition, on-going interagency programs were broadened and important new programs were initiated. A summary of interagency program funding ($\$ \times 10^6$) for the FY-74 to -76 period is presented below.

	FY-74	FY-75	FY-76
USBM	0.9	1.0	-
TVA	0.2	2.7	0.7
TOTAL	1.1 (26)*	3.7 (32)*	0.7 (17)*

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*Percent of total regenerable FGD funding shown in prior Table.

The significantly lower FY-76 funding level for regenerable FGD reflects prior funding of programs which have been completed, are in progress or are being initiated. Funding in FY-76 and subsequent years will be primarily to maintain the overall program discussed in Projection. Barring changes in regulatory emphasis, funding is expected to decline as the technology becomes more established.

CONCLUSIONS

As of November 1975, 115 U.S. flue gas cleaning systems were operational (28 units equivalent to about 5300 Mw), under construction (18 units equivalent to about 6200 Mw), or planned (69 units equivalent to about 33,000 Mw). While non-regenerable systems currently comprise the preponderance of these units, regenerable systems are being installed and planned at an increasing rate. Over the past two years, the power plant capacity controlled by current and projected application of regenerable FGD processes has increased by a factor of ten. During the same period, the ratio of capacity controlled by regenerable processes to capacity controlled by non-regenerable processes has increased by a factor of approximately seven. This rapid growth in the application of regenerable FGD processes is attributable to a great extent to EPA's active past and current programs to support the development of the technology. The need to maintain an active regenerable FGD program is indicated by the advantages of this technology, the fact that regenerable processes comprise the vast majority of second generation systems being evaluated in the U.S. at pilot or larger scale, and by the fact that no near term alternative is likely to displace FGD as the prime means of reducing the environmental impact of using our plentiful coal resources.

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THE EPA PROGRAM FOR CONTROL OF SO_x EMISSIONS FROM STATIONARY COMBUSTION SOURCES NONREGENERABLE FLUE GAS DESULFURIZATION

Michael A. Maxwell
U.S. Environmental Protection Agency
Industrial Environmental Research Laboratory
Research Triangle Park, North Carolina

INTRODUCTION

One of our major energy related environmental problems concerns the need to control sulfur oxide (SO_x) emissions produced during the combustion of fuels. During 1972 over 22 million metric tons of sulfur oxides were emitted from stationary fuel combustion sources. Approximately 55% of this total is directly attributable to the combustion of coal at electric power generating stations.

Given the present state of control technology development, there appear to be three general methods available for substantially reducing stationary source SO_x emissions: (1) using naturally occurring low sulfur coals; (2) desulfurizing or converting the coal prior to combustion; and (3) desulfurizing the gases produced by combustion. Because of the limited availability of low-sulfur fuels and the present state of development of fuel desulfurization/conversion technology, use of flue gas desulfurization (FGD) processes appears to be the major near-term control strategy which will permit the environmentally acceptable use of our vast coal resources.

The 1970 Amendments to the Clean Air Act provided the authority for EPA's current research, development and demonstration program in the FGD area. The primary purpose of this program has been to improve, develop and demonstrate reliable, cost-effective and environmentally acceptable FGD processes for reducing SO_x emissions from both existing and new stationary combustion sources. FGD processes are commonly classified as either regenerable or nonregenerable, depending upon the type of sulfur containing by-product which is produced. Regenerable processes typically produce a saleable product such as sulfuric acid or elemental sulfur while nonregenerable processes generate a waste product such as calcium sulfite or gypsum for disposal. In both the United States and Japan, the majority of full-scale nonregenerable FGD systems applied to utility boilers (either operational, under construction or planned) use lime or limestone as the active alkali.

The more prevalent application of lime/limestone systems (as opposed to regenerable systems) appears related to (1) the early development of lime/limestone processes, (2) their relative simplicity in terms of number of unit operations or process steps required, (3) the availability and widespread distribution of both lime and limestone, (4) the avoidance of potential marketing problems associated with sulfuric acid and sulfur producing systems and (5) the relative investments presently required to construct, operate and maintain these systems. This paper will be limited in scope to dealing with the EPA program in the nonregenerable FGD area.

PROGRAM DISCUSSION

For the past seven years, EPA and its predecessor organizations have conducted a comprehensive research, development and demonstration program in the nonregenerable FGD area. The present program is comprised of tasks covering the following three major technologies: (1) FGD waste disposal/utilization; (2) lime/limestone scrubbing; and (3) double alkali scrubbing.

1. FGD Waste Disposal/Utilization

Since the EPA program in the FGD waste disposal/utilization area is the subject of a separate paper at this symposium, it will therefore not be discussed in detail here(1). However, development of cost-effective environmentally acceptable FGD waste disposal/utilization methods is of particular importance since the production of waste is often pointed out as the most significant disadvantage of lime/limestone FGD systems. Recognizing that fact, EPA has conducted for the past several years a comprehensive program to evaluate, develop, demonstrate and recommend techniques for disposal and utilization of FGD waste. Tasks within this program may be generally classified in the following main categories: (1) environmental assessment of FGD waste disposal; (2) disposal economics; (3) alternate disposal methods; and (4) utilization of wastes.

2. Lime/Limestone Scrubbing

Both in-house and extramural programs directed toward improving the performance and economics of lime/limestone scrubbing are currently being conducted under EPA sponsorship. The primary thrust of this effort involves continuation of the advanced testing program at EPA's prototype test facility located at TVA's coal-fired Shawnee Power Station(2,3). Testing of the 10 MW turbulent contact absorber and venturi/spray tower systems began in mid-1972 with the following major goals: (1) to completely characterize the effect of process variables on SO_2 and particulate removal; (2) to develop mathematical models to permit economic scale-up of attractive operating configurations to full-size scrubber facilities; and (3) to perform long-term reliability testing. With the infusion of Interagency energy funding, the Shawnee test program was expanded in 1974 with the following objectives in mind: (1) to continue long-term testing with emphasis on demonstrating improved reliable operation of mist elimination systems; (2) to investigate advanced process and equipment design variations (e.g. operation with process slurry unsaturated with respect to gypsum) for improving system reliability and process economics; (3) to evaluate process variations showing promise for substantially increasing limestone utilization and reducing sludge production; (4) to evaluate scrubber operability during variable load operation; (5) to investigate methods of improving waste solids separation; (6) to determine the effectiveness of existing technology for producing an improved throwaway waste product, i.e., to evaluate FGD waste oxidation schemes to improve solids settling characteristics and to reduce the chemical oxygen demand of the sludge; (7) to evaluate the effectiveness and environmental acceptability of three commercially offered sludge fixation processes and of untreated sludge disposal; (8) to evaluate system performance and reliability without fly ash in the flue gas; (9) to determine the practical upper limits of SO_2 removal efficiency using lime/limestone scrubbing; (10) to characterize stack gas emissions including outlet particulate mass loading and size distribution, slurry entrainment, and total sulfate emissions; (11) to evaluate the effects of corrosion and wear of plant equipment components and materials; and (12) to develop a computer program for the design and cost comparison of full-scale lime and limestone systems.

Although not yet complete, the advanced test program at Shawnee has produced several interesting and important results to date. First, variable load tests conducted over a period of approximately two months on the venturi/spray tower system at extremely severe operating conditions indicated no problem in either control or reliability of the system. Secondly, limestone utilization comparable to typical lime utilization has been obtained using two different approaches - low pH operation, and by using a three-tanks-in-series reaction tank (to simulate a plug-flow hold tank). Limestone stoichiometries (relative to SO_2 removal) of 1.0-1.2, equating to 83-100% utilization has been obtained. The significance of this observation is that limestone costs approximately $8.00/metric ton compared to approximately $28.00/metric ton for lime; this represents a substantial savings in operating costs. Furthermore, with higher limestone utilization, less waste product is generated which must either be disposed of or chemically treated for disposal. This, in turn, provides even greater potential savings in operating costs and capital investment. Thirdly, a correlation has been observed between alkali utilization and the formation and accumulation of soft mud-type solids, especially in the mist eliminator area. As the utilization is increased, the problem of soft mud-type solids accumulation is decreased or eliminated. When fully confirmed, this could have an immediate impact on existing installed full-scale FGD systems where this problem has persisted.

The EPA in-house FGD pilot plant at RTP has provided experimental support for the Shawnee Test Facility since late 1972. The pilot plant, which includes two scrubbing systems has proven to be a valuable tool for elucidating the chemistry of the SO_2 absorption/precipitation reactions as well as providing flexibility in testing various scrubber configurations and system modifications not easily undertaken with the larger Shawnee prototype. During the past year, efforts have been concentrated at RTP toward (1) improving limestone utilization(4) and (2) oxidizing the calcium sulfite waste to the more desirable and saleable end product, gypsum.(5) Recent EPA pilot plant results have indicated that limestone utilizations exceeding 95% can be obtained concurrently with high SO_2 removal efficiencies by optimizing the two-stage series scrubber and hold tank. It has been further demonstrated that automatic pH control can be successfully applied to systems thus optimized, an approach not practicable in systems of current design which operate at lower (≈70-75%) utilization levels. Additionally, it has been shown that essentially complete oxidation of calcium sulfite waste to gypsum can be achieved at atmospheric pressure under the conditions anticipated with high-sulfur Eastern U.S. coals, without requiring catalysts. In addition to the benefits derived from increased limestone utilization (less limestone required and less sludge produced), the oxidized waste has exhibited improved settling characteristics which will further reduce the volume of waste produced. A study is now underway to determine the modifications necessary to further test these concepts at Shawnee.

The basic responsibility of Shawnee support by the pilot plant has been expanded to include selected short term cooperative efforts with industry. During the past year, undertakings of this nature have included an evaluation of lignite fly ash as an SO_2 scrubbing medium under conditions representative of Western U.S. where lignite deposits are being developed as an important energy resource. This study was made in close cooperation with ERDA and with Sanderson & Porter Engineers, a major design contractor for the Western Utilities, and defined the operating conditions required to successfully meet local SO_2 control regulations using alkaline ash scrubbing. Another such project involved the testing of a special type of limestone, Bahamian Aragonite, for possible use in scrubbers located at East Coast utilities. Demonstration of the efficacy of this material could make possible the application of limestone scrubbing to those seaboard locations where it would otherwise be precluded by lack of space for waste disposal. This approach may also enhance the prospects for conversion of these plants from imported oil to coal.

Other important EPA efforts in the lime/limestone area include the conducting of an intensive test program at Louisville Gas & Electric's Paddys Run Station (full-scale lime scrubbing facility) to fully characterize its performance and reliability in the unsaturated gypsum mode thus broadening its applicability to other utilities. This program is being supported by theoretical/laboratory studies of the calcium-sulfite/calcium sulfate "solid solution" phenomenon in an effort to (1) quantitatively define these variables influencing solid solution formation and (2) develop the theory by which these variables can be related to unsaturated scrubber operations(6). Another program involves evaluation of the Bahco lime scrubbing process as a viable control technology for industrial coal-fired boilers and is currently underway at Rickenbacker Air Force Base. Results of this program could extend the applicability of lime scrubbing to small/medium size industrial and utility area sources.

3. Double Alkali Scrubbing

In addition to EPA's research efforts designed to improve lime/limestone scrubbing, extensive developmental efforts are underway which are directed toward near-term commercialization of double alkali processes for coal-fired utility applications in this country. These processes provide a 2nd generation alternative to lime/limestone scrubbing and offer the promise of significant reliability, performance and cost advantages.(7) Sodium-based double alkali has received the greatest attention in this country with pilot/prototype systems now in successful operation at a number of industrial boilers and one 20 MW coal-fired utility boiler. In Japan a number of sodium-based double alkali systems are presently operating at a commercial scale applied to oil-fired boilers.

The EPA program in the double alkali area begun in 1972 with in-house laboratory/pilot studies at RTP. The program was subsequently expanded in 1973 to include extramural work with Arthur D. Little/Combustion Equipment Associates, Gulf Power/Southern Services and General Motors at the laboratory/pilot/prototype level.(8) The objectives of the program were to define the most promising sodium-based double alkali modes of operation and to characterize these modes with regard to SO_2 removal, reactant yields, sulfite oxidation, sulfate regeneration, waste solids characteristics, soluble solids losses, and overall process reliability.

The culmination of the EPA program in this area will involve a contract with a host utility to demonstrate a sodium-based double alkali process applied to a 100 MW or larger high sulfur coal-fired utility boiler. Procurement activities associated with the project are currently underway. Acceptable proposals have been received from three utility/process vendor teams. The final selection and award of contract should be complete by June 1976. Design and construction of the full-scale system is expected to be complete by late 1978 followed by a one-year comprehensive test program (formulated and performed by an independent 3rd party) to completely characterize the system.

INTERAGENCY PARTICIPATION

Prior to FY 74, EPA efforts in the nonregenerable FGD area were funded entirely from EPA's base budget. When Interagency funds to supplement the Nation's energy program became available in 1974, a portion of these funds was applied to the Federal program in the nonregenerable FGD area. In 1974, Interagency energy funding covered approximately 25% of the total nonregenerable FGD program and 100% in FY 75 and 76. All Interagency energy funded work in this area is being administered by EPA either in-house or by means of contracts/grants. Additionally, a significant part of this work is being performed by other Federal agencies such as TVA with funds provided by EPA. The most notable example involves TVA's important role in operating and maintaining the EPA Shawnee test facility described earlier. Other EPA funded FGD work is being performed under cooperative/cost-shared arrangements with municipal or industrial organizations.

RESOURCE ALLOCATION

Since the late 1960's, the development of nonregenerable FGD control technology for SO_x stationary source emissions has been a major component of EPA's research program. The total resource allocations since 1974 and projected through 1976 are summarized as follows ($\$x10^6$).*

FY 74		FY 75		FY 76	
Base	Interagency	Base	Interagency	Base	Interagency
0.58	1.80	0	19.71	0	5.48

CONCLUSIONS

The application of nonregenerable FGD technology has progressed rapidly over the past several years. A number of commercial lime/limestone FGD installations applied to coal-fired utility boilers are currently achieving high SO_x removal efficiency with good reliability. In addition, over 38,000 MW of FGD capacity is either under design/construction or in the planning stages. EPA's research and development program has been instrumental in accelerating the commercial viability of this technology. In particular, the EPA Shawnee lime/limestone test facility and IERL-RTP's in-house pilot plant have generated valuable data which have proven useful in improving the performance and reliability of lime/limestone systems.

However, additional work remains to be done in the nonregenerable FGD technology area including (1) the continued assessment and development of cost-effective environmentally acceptable disposal/utilization technology for the waste produced from lime and limestone systems; (2) the development and demonstration of improved lime and limestone process variations which will minimize cost and energy usage and further improve scrubber system reliability and performance; and (3) development and demonstration of the double alkali process as a 2nd generation alternative to lime/limestone processes.

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*Does not include funding in the FGD waste disposal/utilization area. Does include funds passed through to other Federal agencies.

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Development of Combustion Modification Technology for Stationary Source NO_x Control

G. Blair Martin
J. S. Bowen
Combustion Research Branch
Energy Assessment and Control Division
Industrial Environmental Research Laboratory-RTP

One of the major classes of pollutants emitted into the atmosphere from man's activity is identified by the term nitrogen oxides (NO_x). Approximately 99% of the NO_x is generated from combustion of fuels in a variety of equipment types. The evidence indicates that for most equipment types 95% of the NO_x is emitted from the source as nitric oxide (NO) with the balance being nitrogen dioxide (NO_2); however, recent results indicate that for certain sources (e.g., gas turbines) the percentage of NO_2 may be significantly higher. In any event, the total NO_x emitted undergoes a complex scheme of atmospheric photochemical reactions with hydrocarbons and sulfur oxides. These reactions result in the formation of undesirable secondary species, such as ozone and nitrates, and in a shift of the residual NO_x toward NO_2. The recognition of the adverse effects of NO_2 and other atmospheric pollutants on human health and welfare led to passage of the Clean Air Act of 1970. As a result of this act the EPA was empowered: 1) to establish a National Ambient Air Quality Standard (NAAQS) for NO_2; 2) to require a 90% reduction of NO_x from the automobile; 3) to establish New Source Performance Standards for stationary equipment; and 4) to set up mechanisms to insure compliance.

At the time the Clean Air Act was passed, mobile and stationary sources each contributed approximately 50% of the NO_x and the major control strategy was reduction of mobile source emissions by 90% to 0.4 gms of NO_2 per mile (0.25 mg of NO_2 per metre). NSPS were provided to reduce growth of NO_x emissions from stationary sources. Since that time a number of factors have emerged which appear to require some modification of this approach to NO_x control. First, development of economic control technology to meet the automobile emission goal has proved elusive. Second, the energy crisis has provided strong pressure for use of coal in utility boilers with an attendant increase in NO_x emissions. These factors and others have resulted in a greater emphasis on NO_x control for stationary sources and in a recommendation for a Maximum Stationary Source Technology (MSST) program for control technology development.(1)

There are a number of potential approaches to control of NO_x from stationary combustion sources including:

(1) Combustion modification, which is based on alteration of combustion conditions to minimize formation of NO_x, is potentially applicable to all types of combustion sources both new and existing;

(2) Flue gas treatment, which involves an add-on device to remove the NO_x from the flue gas, is currently envisioned as a method to supplement combustion modification where a high degree of control is required;

(3) Advanced alternate fuels and combustion processes may have properties leading to inherently low levels of NO_x;

(4) Fluid bed combustion, which is predominantly a SO_x control technique, has favorable characteristics for NO_x reduction, especially with application of combustion modification principles.

The purpose of this paper is to describe the Combustion Modification program as related to items (1) and (3) above. Flue gas treatment and fluid bed combustion programs are described elsewhere in this symposium.

BACKGROUND

The combustion modification approach is based on the premise that NO_x can be reduced substantially by alteration of the conditions under which the fuel burns. There are two predominant mechanisms for the formation of NO_x during combustion. Thermal NO_x is formed by fixation of molecular nitrogen from the combustion air through a series of reactions which are exponentially dependent on temperature and slightly dependent on oxygen availability. Fuel NO_x is formed by oxidation of organic nitrogen compounds contained in the fuel through a series of reactions which are relatively independent of temperature and strongly influenced by oxygen availability. For any fuel containing bound nitrogen both mechanisms contribute to the total NO_x formation.

Working from this knowledge of the NO_x formation chemistry, a number of control technology approaches have been formulated. Techniques for control of thermal NO_x are based on reducing the peak temperatures in the combustion zone, and include staged combustion, low excess air, flue gas recirculation and water injection. Techniques for control of fuel NO_x are based on reduction of oxygen availability in the combustion zone, and include low excess air operation and staged combustion. In addition, pilot scale combustion studies have shown that changes in burner design can also significantly reduce the formation of both thermal and fuel NO_x by aerodynamically influencing local recirculation rates and/or oxygen availability in the flame. The optimum level of control may require a combination of these approaches. Although the control techniques have shown good potential in experimental systems and on some practical equipment, the optimum levels achievable have yet to be established and are the subject of this program. In the application of NO_x control technology to practical equipment care must be taken to minimize potential adverse side effects. These include: increases of other pollutants, loss of system efficiency, and system operability problems. Based on current information, emissions of other pollutants (e.g., carbon monoxide and other products of incomplete combustion) can be maintained at low levels while achieving significant NO_x reduction by proper system design. Many of the NO_x control techniques, such as low excess air operation, even offer potential for increases of system efficiency. Based on limited experience with long term service it appears that operability problems, including fireside corrosion, can be avoided by proper design.

COMBUSTION MODIFICATION PROGRAM

The NO_x control technology development program was initiated in 1969 at the conclusion of a systems study conducted under contract by Esso Research and Engineering.(2) The system study provided an emission inventory by source category and fuel usage; in addition, it reviewed the available technology and development potential of various control approaches and concluded that the combustion modification techniques to reduce NO_x formation offered the most cost effective potential. Based on this study and the available resources, a Combustion Modification R&D program was structured to develop and apply control technology for the equipment type and fuel combinations which constituted the major stationary sources of NO_x. These major sources are shown in Table 1 based on a recent updated emission inventory.(3) In addition, the NO_x control technology developed was to be capable of minimizing undesirable side effects of the technology, and maintaining or improving process energy efficiency. Ongoing developments in the private sector (e.g., gas and oil fired utility boilers) were considered to insure complementary activity where appropriate and to avoid duplication where significant private effort exists. Details of the program have been documented in detail in two recent papers.(4,5)

This basic philosophy has been followed, although in the intervening years the program emphasis has been expanded and shifted to account for recent trends. As an example, in response to the recent increase in emphasis on stationary source NO_x control and the Clean Air Act requirement for demonstrated technology as the basis for any NSPS, IERL-RTP has Aerotherm working under contract to establish the requirements for a Maximum Stationary Source Technology (MSST) program. The first inventory identified 137 combinations of equipment type and fuel that account for the stationary source NO_x of which 38 contribute 90%.(3) While this appears to be a formidable number of combinations, there are many common features of the systems which allow general application of the technology and, therefore, a manageable development effort. A report containing the final recommended program and funding levels is currently in preparation.

The general program approach involves five types of activities. Field testing provides accurate emission information on the source class as normally operated in the field and evaluation of control possible through changes in operating conditions only. Process R&D evaluates the potential for minor hardware changes for increased level of control by retrofit and, thereby, provides guidance for application of existing technology to new designs. Fuels R&D provides general development of various techniques for controlling NO_x from each fuel type independent of equipment type, optimization of the technology for each fuel, and general guidance for application of the optimum technology to a variety of practical systems. Fundamental studies of combustion chemistry and aerodynamics promote understanding of the combustion phenomena responsible for pollutant formation and, thereby, guide development and optimization of new technology. Environmental assessment documents the impact of the NO_x control technology on total system performance and emissions to air, water and land.

PROGRAM STATUS

The results of the program to date fall into two general areas: 1) Development and application of control technology to specific source categories, and 2) Generation of technology approaches of potential applicability to a wide range of sources.

The development and application of technology for specific practical equipment has concentrated on the major heat and steam generating sources of NO_x. These are utility, industrial and commercial boilers, and residential heaters. The significant results to date can be summarized as follows:

1) Utility boiler field testing has established reliable emission factors for boilers fired with coal, oil and natural gas and has indicated that significant levels of control are achievable through modification of operating conditions with the specific level of control dependent on fuel type and boiler design. In addition, it has been shown that by minor hardware modifications to apply staged combustion, NO_x levels can be reduced by 30-40% for coal fired boilers already operating at or slightly above the NSPS for that type of equipment. Efficiency and fireside corrosion results are encouraging but show that more attention to these areas is necessary.

2) Industrial and commercial boiler field testing has also established reliable emission factors for a variety of fuels; however, it has indicated that the relatively simple designs of these boilers make them

less amenable to NO_x control by possible changes in operating conditions. The development and application studies, in which the emphasis has been on small package type boiler fired with heavy oil and natural gas, have shown the potential for NO_x reductions of up to 50% for the heavy oil by application of staged combustion and over 60% for gas with flue gas recirculation.

3) Residential furnace emission factors have also been established; however, changes in operating conditions, which consist of tuning, generally increase NO_x slightly. The development effort has produced an oil burner head design capable of reducing NO_x relative to conventional practice. Further development of an integrated furnace to achieve a 50 to 75% reduction of NO_x coupled with an efficiency increase is nearing completion. Field application has not yet been attempted.

The development of advanced technology approaches consists of investigations in three general areas: optimization of burner design and other techniques to establish minimum NO_x emissions achievable for conventional fuels and system design; assessment of alternate fuels and equipment design approaches for ultimate control potential through system redesign; and fundamental studies to provide understanding and guidance for the first two areas. Selected significant results in each area are given below:

1) Major effort for development of optimized technology has concentrated in the area of burner design alteration to give low NO_x and efficient combustion conditions. Critical parameters have been established for natural gas and pulverized coal and progress has been made for residual oil. Possibly the most significant result was establishing conditions capable of reducing NO_x from a single pulverized coal burner from approximately 900 ppm to approximately 150 ppm.

2) Advanced concept studies which have been initiated include alternate fuel combustion and catalytic combustion. The only alternate fuel evaluated to date is methanol, which appears to have favorable combustion and emission characteristics.

3) The fundamental studies have produced kinetic rate information for gas phase and fuel decomposition reactions, as well as basic aerodynamic mixing information for turbulent diffusion flames. This information provides input for development of engineering design models for application and optimization of the technology.

PROGRAM DIRECTION AND GOALS

The program direction and goals are strongly dependent on both the level of funding and the duration of the program. Table 2 has been prepared to show approximate current emission levels for uncontrolled sources and the estimated level of NO_x control achievable in 1980 and 1985 for the 10 year MSST. The near term goals should be possible with hardware changes (e.g., burner design) for conventional boiler design, while the long term goals may depend on significant system redesign and/or application of advanced concepts. Although the technology to achieve these levels can almost certainly be developed by the year shown, the demonstration in practical equipment will depend on equipment lead time and other factors, particularly for the larger systems (e.g., utility boilers). For less than a maximum program lower priority sources will be dropped from consideration. Based on the current projected funding and a program duration of 5 years, the probable achievable technology and demonstration goals are indicated by notation on 1980 goals in Table 2. The other 1980 goals are achievable, but are not currently under intensive development. This technology also has the potential for application to current equipment with a lower probable degree of control. The 1985 goals would be outgrowths of the technology with significant system redesign (i.e., combustion and heat exchanger design matching) and/or utilization of advanced technology under development currently (e.g., catalytic combustion).

To illustrate the total approach consider the overall development history for wall fired coal burning utility boilers shown in Table 3. Given the significant decrease available by relatively minor changes in hardware and operating conditions coupled with the low level achievable on a small coal burner at the International Flame Research Foundation, achievement of 200 ppm in a field operating utility boiler by application of an optimum burner can be projected with high probability.

A second example can be taken for residential heating systems to illustrate not only NO_x control with no increase of carbonaceous emissions, but also improved efficiency. This can be represented by Figure 1, which shows a reduction in NO_x attributable to an optimized burner and a further reduction attributable to an integrated burner furnace. The reduction in NO_x is accompanied by a reduction in excess air at the operating condition which results in an efficiency increase of over 5%. Emissions of carbonaceous species are essentially unchanged and remain at typically low levels.

Finally, the exploration of advanced concepts and utilization of alternate fuels may provide the basis for longer term (1985) technology to virtually eliminate NO_x emissions from some sources. For bound-nitrogen-free fossil and coal derived fuels, catalytic combustion concepts may allow NO_x to be controlled to the level of 10 ppm or less. Control of NO_x from nitrogen-containing alternate fuels appears somewhat more complex; however, it appears that this combustion technology should also be applicable.

INTERAGENCY PARTICIPATION

A substantial portion of the NO_x control technology development program is being funded by Interagency supplemental energy funds (see following section on Resource Allocation). The work is being performed principally by private organizations under grant or contract to EPA. Some work is being funded by Interagency Agreements between EPA and other government agencies who are performing the work. EPA also maintains an in-house R&D effort on NO_x at IERL-RTP.

RESOURCE ALLOCATION

Since the early 1970's, the development and control of NO_x emissions has been a major component of EPA's program to develop control technology for stationary source emissions. EPA's base program was substantially augmented by Interagency energy supplement funds in 1974 and subsequent years, and currently the energy funds account for essentially all program resources. The total resource allocations since 1974 and projected through 1976 are as follows ($ x 10):

FY 74		FY 75		FY 76	
Base	Interagency	Base	Interagency	Base	Interagency
2.64	2.35	1.95	3.8	0	5.9

CONCLUSIONS

The developing combustion modification technology can form the basis for significant New Source Performance Standards in the future for several stationary combustion systems. Implementation of a 10 year MSST strategy can significantly broaden the degree of control and demonstrated source application achievable with the technology. It also appears that any adverse impacts of NO_x control on cost, energy efficiency, and other emission can be minimized or eliminated by proper technology application.

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Table 1. - Summary of Total NO_x Emissions from Fuel User Sources (1972)

Sector	NO_x Production (percent of total) Gas	Coal	Oil	Totals by Sector (percent of total)	Cumulative Percentage
1. Utility Boilers	9.55	32.47	6.59	48.61	48.61
2. IC Engines					
Reciprocating	16.06	—	2.71	18.77	67.38
Gas Turbines	1.47		1.02	2.49	69.87
3. Industrial Boilers	4.24	4.41	9.41	[illegible]	87.98
4. Commercial/Residential Heating	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5. Process Heating	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6. Non-Combustion	—			[illegible]	99.66
7. Incineration				[illegible]	100
Totals by Fuel	[illegible]	[illegible]	[illegible]	100	

Total Emissions = [illegible]

Table 2. - New System Goals--Average NO_x (ppm @ 3% O_2)

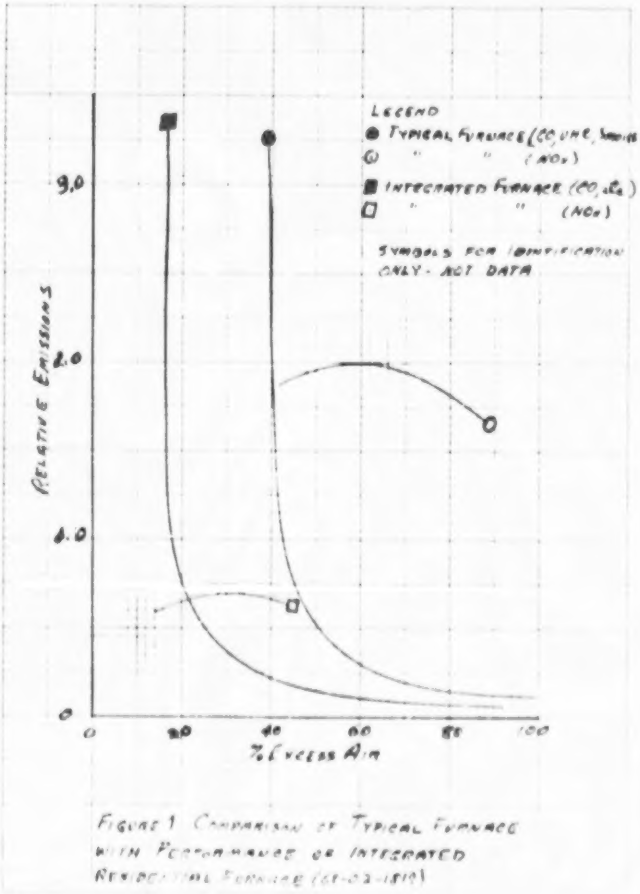
Source	Current Technology	[illegible] Goal	[illegible] Goal
Utility			
Gas	[illegible]	[illegible]	[illegible]
Oil	[illegible]	[illegible]	[illegible]
Coal	[illegible]	[illegible]	[illegible]
Industrial			
Gas	[illegible]	[illegible]	[illegible]
Residual oil	[illegible]	[illegible]	[illegible]
Coal	[illegible]	[illegible]	[illegible]
Commercial			
Gas	[illegible]	[illegible]	[illegible]
Distillate oil	[illegible]	[illegible]	[illegible]
Residual oil	[illegible]	[illegible]	[illegible]
Residential			
Gas	[illegible]	[illegible]	[illegible]
Distillate oil	[illegible]	[illegible]	[illegible]
Reciprocating Engines			
Spark ignition gas	[illegible]	[illegible]	[illegible]
Compression ignition (oil)	[illegible]	[illegible]	[illegible]
Gas Turbines			
Gas	[illegible]	[illegible]	[illegible]
Oil	[illegible]	[illegible]	[illegible]

(a) Current NSPS
(b) Estimated achievable with [illegible] control technology
(c) Developed and field applied technology
(d) Developed technology

Table 3. - Example Control Development History Wall Fired, Coalburning Utility Boiler

Event	NO_x Level ppm @ 3% O_2	Year Achieved Actual	Projected
1. Uncontrolled	[illegible]	Pre-1971	
2. Boiler Operation Change	[illegible]	1971	
3. NSPS	[illegible]		[illegible]
4. Modified Burner	[illegible]	[illegible]	
5. Small Scale Single Coal Burner (Experimental)	[illegible]	[illegible]	
6. Full Scale Optimum Single Coal Burner (Experimental)	[illegible]		[illegible]
7. Multi-Optimum Burner	[illegible]		[illegible]

Figure 1. - Comparison of Typical Furnace with Performance of Integrated Residential Furnace (68-02-1819)



THE EPA DEVELOPMENT PROGRAM FOR NO_x FLUE GAS TREATMENT

Richard D. Stern
U.S. Environmental Protection Agency
Industrial Environmental Research Laboratory
Research Triangle Park, North Carolina

Stationary combustion sources contribute about one-half of the man-made nitrogen oxides (NO_x) emitted to the atmosphere in the United States. Because of the quantity of NO_x emissions and the known adverse health and ecological effects associated with ambient NO_x, EPA has undertaken a research program under authority of the 1970 Clean Air Act. The purpose of the program is to develop and demonstrate cost-effective, commercially-viable methods for controlling NO_x emissions.

EPA's overall strategy for NO_x control, Maximum Stationary Source Technology (MSST), is designed to increase the degree and effectiveness of control from existing and new stationary sources because of difficulties in achieving desired levels of control from mobile sources. The MSST strategy is not fully defined but is currently viewed as a ten-year program. This strategy has not as yet produced changes in the emission standards for stationary sources, but such standards may be made more stringent as health effects and atmospheric chemistry studies progress. A short term ambient standard to supplement the current annual average appears to be a strong possibility.

EPA's overall program for controlling NO_x emissions from stationary sources includes two main technologies: (1) Control of combustion processes (Combustion Modification--CM); and (2) Control of post combustion products (Flue Gas Treatment--FGT). CM minimizes the formation of NO_x during combustion, and is discussed in a separate conference paper. FGT removes nitrogen oxides from the gaseous products of combustion.

Combustion modification, though inexpensive, is limited in terms of NO_x reduction efficiency, particularly on coal-fired sources. Additionally, the practical limitations and secondary effects of combustion modification have not as yet been assessed. Due to the efficiency limitation and possible secondary effects associated with combustion modification, NO_x FGT has, for some time, been considered to be a possible "add-on" technology for use when high removal efficiencies are called for or when the source under consideration is not amenable to extensive control by combustion modification. Research effort in the FGT area has been minimal due to uncertain need and unfavorable initial results. However, recent emphasis of stationary source NO_x emission control has resulted in an expanded program for NO_x FGT development by EPA.

TECHNICAL DISCUSSION

NO_x in combustion flue gas exists almost entirely as NO. At normal flue gas exit temperatures, air oxidation of NO proceeds too slowly to be of use in processes for treatment of flue gas for NO_x removal. Since NO is not easily absorbed by any readily available scrubber liquor, the problem of removing NO_x from flue gas becomes one of either reducing NO to elemental nitrogen or oxidizing NO to the more reactive NO_2 or N_2O_3 forms for subsequent absorption in scrubbing liquor. For convenience of discussion, these two process routes can be categorized as dry processes (reduction) and wet processes (oxidation followed by scrubbing).

1. Dry Processes

Although there are many theoretical dry process variations (e.g., non-selective reduction, selective reduction using NH_3, CO or H_2, and molecular sieves), only selective catalytic reduction using ammonia has achieved notable success in treating combustion flue gases for removal of NO_x. The presence of oxygen in concentrations many times greater than NO_x in combustion flue gas essentially precludes consideration of non-selective reduction and the achievement of selective reduction with a reductant other than ammonia has proven difficult. Due to preferential sorption of moisture and resultant loss of active sites, molecular sieves are not applicable for control of NO_x from combustion flue gas. Selective reduction of NO_x using ammonia is readily accomplished using any of number of catalysts.

The fundamental reactions for the ammonia reduction processes are:

$$6NO + 4NH_3 \rightarrow 5N_2 + 6H_2O \qquad (1)$$

$$2NO + 2NH_3 + 1/2O_2 \rightarrow 2N_2 + 3H_2O \qquad (2)$$

Data indicate that reaction (2) predominates. In general, reaction temperatures range between 250°C and 450°C with NH_3/NO_x mole ratios of approximately 1.0 to 1.5. Each process developer utilizes different catalysts, catalyst supports and bed configurations. Also, differing applications require substantially different catalysts and operating conditions depending upon the SO_2 content and dust loading of the specific flue gas. The inlet NO_x concentrations being treated in Japan range from 150 ppm to 250 ppm with NO_x exit concentrations of 10 ppm to 50 ppm.

Japanese firms have operated pilot and prototype selective reduction units for more than two years. Commercial scale units are operating on natural gas fired sources and large commercial-scale units are currently under construction for a number of oil-fired sources. To date, there are no known applications of selective reduction processes to coal-fired flue gas.

The considerable experience in Japan no doubt qualifies NO_x flue gas treatment by selective catalytic reduction as commercially available for application to gas- and oil-fired sources in the U.S. from a technical standpoint. There are, however, several factors and questions which must be considered in determining the potential for widespread use of this technology in the U.S. Of particular importance is the applicability of this technology to coal-fired sources. The IERL-RTP NO_x flue gas treatment program discussed in PROGRAM DISCUSSION and PROJECTION is aimed at resolving these questions.

2. Wet Processes

Although the chemistry and process steps involved in wet processes are considerably more varied than in dry processes, nearly all of those systems which have advanced beyond bench scale involve the use of a strong oxidant such as ozone or chlorine dioxide to convert the relatively inactive NO in the flue gas to NO_2 or N_2O_5 for subsequent absorption. Unfortunately, nearly all wet processes result in a troublesome by-product which is, in most cases, of little or no commercial value. In general, wet processes are less well developed and show higher projected costs than dry FGT processes. Considering their cost and complexity, it is doubtful that wet processes would be receiving any development attention in Japan were it not for the potential for simultaneous SO_x and NO_x removal.

The required oxidation for wet FGT processes can take place either in the liquid or gas phase. Those processes that utilize liquid phase oxidation require extensive liquid/gas contact in order to absorb the inactive NO. It appears that the size and pressure drop of the NO absorber may be so great as to preclude the use of liquid phase oxidation processes on combustion flue gases where large volumes of gas and low NO_x concentrations are involved. The use of ozone or chlorine dioxide to oxidize NO in the gas stream prior to the scrubber appears to be the more successful approach. Although the required scrubber is still quite large, substantial removal of NO_x can be obtained in scrubbers designed for SO_2 removal. Unfortunately, chlorine dioxide is expensive and its use introduces the problem of disposing of chloride-containing liquid discharges, and the production of ozone requires massive amounts of electrical energy and expensive equipment. For coal-fired flue gas with its higher NO_x concentrations, the cost of oxidant is very likely to be prohibitive. Also, where ozone is utilized, additional equipment may be required for removal of ozone from the exit gas stream.

Although wet NO_x FGT systems are not likely to see widespread use in this country, two deserve additional mention because they are relatively simple extensions of well established flue gas desulfurization (FGD) technology. The Chiyoda 101 FGD process has been modified by the inclusion of an ozone generator for NO oxidation. The absorbed NO_x is removed from the system as a dilute calcium nitrate solution requiring disposal. The process has been designated Chiyoda Thoroughbred 102. This simultaneous SO_x/NO_x process has been piloted in Japan but has not seen commercial service as yet. Mitsubishi Heavy Industries (MHI) also is developing a wet NO_x FGT process which is a fairly simple extension of their limestone FGD process. In this case, two additional pieces of equipment are required: one for ozone generation and injection into the flue gas, and one for treatment of the tail gas to remove unreacted ozone prior to release to the atmosphere. The MHI process differs from most other wet FGT processes in that the captured nitrogen oxides are reduced to elemental nitrogen by reaction with calcium sulfite in the circulating scrubber liquor. A proprietary catalyst is present in the scrubber liquor to promote this reaction. This simultaneous SO_x/NO_x process is also being piloted in Japan at this time. Both the Chiyoda and MHI processes are attractive from the standpoint of having simultaneous SO_x/NO_x control capability and from the developmental standpoint since they involve already commercial FGD technology; however, both require the use of ozone. Ozone production for application to coal-fired flue gas is expected to require approximately 10 percent of the power plant electrical output. When added to the power requirement of the FGD portion of these processes, this energy consumption is likely to render wet simultaneous SO_x/NO_x processes impractical for commercial use.

There appears to be no question that wet NO_x FGT systems can not compete with dry selective catalytic reduction where simple NO_x control is involved. For coal-fired applications where high dust loadings and SO_2 removal are involved, it is not as yet clear whether dry FGT combined with conventional FGD processes will be cheaper than the wet simultaneous SO_x/NO_x systems such as Chiyoda 102 or MHI. Dry simultaneous SO_x/NO_x systems such as the Shell and the Sumitomo Shipbuilding processes may also prove to be cheaper than the wet simultaneous processes. The Shell process is being commercially applied on a 40 Mw oil-fired boiler in Japan and is being piloted in the U.S. on a 0.6 Mw equivalent flue gas stream from a coal-fired boiler. The Sumitomo Shipbuilding process will be tested at the prototype level on an oil-fired boiler in Japan.

The IERL-RTP NO_x flue gas treatment development program is aimed at resolving these issues in order that the Agency's NO_x strategy can be based on sound technical and economic information and to ensure that the most promising developmental routes are followed.

PROGRAM DISCUSSION

Through FY-1973 about $975,000 was allocated to the EPA NO_x flue gas treatment technology. The activity consisted of system studies, grants, and in-house work. Results indicated that sulfuric acid scrubbing and alkaline scrubbing were not feasible for control of flue gas NO_x (about 95% NO and 5% NO_2) or even equimolar mixtures of NO and NO_2 because of low mass transfer rates leading to large equipment and high costs. In most cases, NO went through the system relatively unaffected. Although the potential for NO_2 removal with alkaline solutions was indicated, studies on the oxidation of NO to NO_2 indicated that this step was very expensive and required high energy consumption. Catalytic reduction was identified as a promising approach and two programs were initiated. One was a 2 Mw pilot plant evaluation of a noble metal (Pt) catalyst with NH_3 reductant at a gas-fired utility and the other was a laboratory evaluation of about 45 different catalyst/reductant systems.

During FY-74 budget planning, emphasis was put on combustion modification only and no new funds were allocated to FGT. The on-going FGT work proceeded, however, and resulted in demonstrated high NO_x removal (85% to 95%) on the gas-fired pilot plant and identification of two promising non-noble metal systems with potential for operating in flue gases containing SO_x. Emphasis was increased in FY-1975, and $250,000 was allocated for technology development. The pilot plant work was expanded to evaluate the catalyst/reduction system on low sulfur residual oil-fired flue gas and a laboratory program was initiated to further evaluate the non-noble metal catalyst systems and develop data for scale-up to pilot stage. In addition, environmental assessment activities were initiated to determine new control requirements and control strategy technology mixes in a major metropolitan area, and to estimate ammonia and oxidant supply/demand, production economics, and energy consumption.

PROJECTION

Current and future plans call for continued strategy and environmental assessment activities to determine the need for NO_x flue gas treatment and technology approaches. These efforts are currently underway. Japanese technology is expected to play a major role in NO_x FGT projects due to its advanced state.

Efforts are proceeding on this basis and discussions have been held with U.S. and Japanese firms. A Commerce Business Daily advertisement was issued January 9 stating that sources are sought to participate in several projects leading to the demonstration of NO_x flue gas treatment technology for possible use on utility and industrial combustion sources. It is expected that initial projects will be at the pilot (0.5 Mw to 5 Mw) scale or possibly prototype (5 Mw to 20 Mw) scale. Major emphasis will be placed on treatment of coal-fired flue gas. The number and size of projects to be undertaken will be a determined by budgetary constraints, availability of cost-sharing funds from industry, and the state-of-the-art of available technology. Projects are envisioned in three possible application categories: (1) Removal of NO_x from coal-fired flue gas containing low SO_2 concentrations, such as flue gas from low sulfur coal-firing which complies with New Source Performance Standards for SO_2. (2) Removal of NO_x from coal-fired flue gas containing high SO_2 concentrations (1500 ppm to 3000 ppm). (3) Simultaneous removal of SO_x and NO_x from coal-fired flue gas. The sources sought fall into two categories: process developers or vendors, and host sites. This advertisement was distributed extensively in the U.S. and Japan.

To ensure that the process selections for these projects are based on the best available information, a continuing program of technology assessment will be carried out utilizing consultants, contractors, and actual site visits. Communication with Japanese firms through a skilled Japanese consultant will also be continued. The program is aimed at determining the following: (1) The impact of the higher dust loadings, high chloride concentration, higher oxygen concentration and higher inlet NO_x concentrations associated with coal-fired flue gas. (2) The potential secondary problems of emissions such as catalyst particles, ammonia, ozone or other oxidants, and effluents such as nitrates, sulfates or nitric acid. (3) The capital and operating costs of NO_x FGT processes applied to a coal-fired boiler. (4) The material/energy consumptions associated with the various NO_x FGT processes and impacts on supply/demand.

INTERAGENCY PARTICIPATION

Thus far the NO_x FGT program has not reached the stage where active interagency participation has been warranted. However, as the program advances, interagency participation in areas such as cost sharing, provision of a host site, process evaluation, and economics are clearly indicated. Some preliminary discussions have been held.

RESOURCE ALLOCATION

Tabulated below is a funding history (in $1000s) of the NO_x FGT program.

FY-69	FY-70	FY-71	FY-72	FY-73	FY-74	FY-75	FY-76
43	16	83	269	567	0	250*	632

*Includes $200,000 energy supplemental funding.

Although past funding has been minimal, the undertaking of several parallel "hardware" projects will require substantial funds in the future. These funds can also be supplemented by money in the SO_2 program that is earmarked for simultaneous SO_x/NO_x removal work. Furthur, the program is predicated on substantial cost sharing by industry on the planned "hardware" projects. It is anticipated that the program would proceed with relatively small scale work in parallel with environmental assessment activities. Large scale demonstration activities would be initiated following clarification of control strategies and technologies. The planned program is expected to lead to demonstrated technology available for application to different types of sources by the early 1980's. It is also intended that the economics and secondary effects of these systems be well defined in order that NO_x control strategies can be implemented with the least adverse impact on both the economy and the environment.

CONCLUSIONS

1. Difficulties and high costs associated with achieving substantial reductions in NO_x produced from mobile sources have resulted in a renewed emphasis on NO_x control of large stationary sources. In addition, based on health effects and atmospheric chemistry studies and proposed amendments to the Clean Air Act, there exists a real possibility that the future will see a tightening of NO_x standards.

2. Combustion modification is an inexpensive and effective method for achieving reduction of NO_x from stationary combustion sources. It is, however, limited both in emission reduction efficiency and range of applicability, particularly for coal-fired sources. NO_x flue gas treatment provides an "add-on" technology to be used in addition to combustion modification when high removal efficiencies are called for.

3. The Japanese, due to very stringent NO_x regulations, have progressed to the point of commercial application of NO_x flue gas treatment systems. The work to date has, unfortunately, been conducted only on gas- and oil-fired sources. Experimental work with coal-fired flue gas is needed before meaningful projections of the usefulness of NO_x FGT for coal-firing can be made.

4. A number of important questions concerning costs, secondary effects, materials use, reliability, waste disposal, etc., must be answered through a coordinated program of experimental work on coal-fired flue gas, technology assessment, and engineering studies. The EPA research and development program for NO_x FGT has been formulated to provide continually updated estimates and assessments for input into control strategy/technology development and to provide demonstrated technology by the early 1980's.

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CONTROL OF FINE PARTICULATE EMISSIONS FROM STATIONARY SOURCES

James H. Abbott

Environmental Protection Agency
Industrial Environmental Research Laboratory
Research Triangle Park, North Carolina

Fine particulates are a health hazard because in contrast to coarse particles they can bypass the body's respiratory filters and penetrate deeply into the lungs.[1,2] Fine particles released into the atmosphere remain airborne for extended periods of time, obstruct light and cause limited visibility typical of air pollution, haze and smog. They have been identified as transport vehicles for gaseous pollutants. The health hazards of fine particulates are intensified by the tendency of metallic materials from high-temperature processes, such as pyrometallurgical and combustion processes, to condense as chemically and catalytically active fine particles. Many toxic and potentially hazardous compounds are also emitted as fine particulate.[1] Particulate matter formed in the atmosphere from chemical reaction and condensation is called secondary. The phenomena associated with the formation and transport of secondary particulate make it difficult to relate atmospheric particulate pollution levels to specific sources. This problem has hampered the development of effective, fine particulate control strategies and the establishment of meaningful fine particulate emission standards. The control of these secondary forms of particulate must be through control of their precursors, and it is generally thought that primary emitted particulate plays an important role in the formation cycle.

Many years will be required to develop a sound data base to quantify the health effects problem of fine particulates. Sufficient information does exist, however, to conclude that fine particulates must be controlled if public health is to be protected.

EPA and predecessor organizations have been involved in development of systems for control of emissions from industrial sources, including those that are energy-related, for many years. Their first work on control of particulate emissions dates back to 1958. Because of the importance of energy production in the emission of these major pollutants, recent activities have focused on energy-related processes, particularly the conventional power plant.

In order to pursue the goal of developing control technology for fine particulate emissions the current basic EPA fine particulate program has been divided into six main areas.

1. Measurement.
2. Characterization and Improvement of Conventional Control Equipment and Assessment of the Collectability of Dusts.
3. New Particulate Control Technology Development.
4. New Idea Identification, Evaluation, and Technology Transfer.
5. High-Temperature and High-Pressure Particulate Control.
6. Accelerated Pilot Demonstrations.

Elaboration on each of these program areas will follow in the succeeding discussion.

TECHNICAL AND PROGRAM DISCUSSION

1. Measurement

Current devices used for measuring particle size on control equipment include impactors, optical counters, diffusion batteries, and condensation nuclei counters. These devices require lengthy manual techniques for operation and their reliability is less than satisfactory.[3] For instance, with current measurement technology, it is not always possible to discern the difference between a device collecting 90% of particles less than 0.5 microns in size and one collecting 95% or sometimes even 99%. If we are to maintain our momentum in control technology development, this situation must be remedied.

It is the objective of the EPA effort in this area to produce a device which will continuously measure fractional efficiencies of control devices in real time with a high degree of precision and accuracy in a plant environment.

2. Characterization and Improvement of Conventional Control Equipment and Assessment of the Collectability of Dusts

a. Electrostatic Precipitators (ESPs) - The EPA has completed the total characterization of seven ESPs operating on a number of sources ranging from power plants to aluminum plants.[4,5,6] Data from these tests have clearly shown that ESPs can collect particles of all sizes with high efficiency when dust resistivity is not a problem. Data and theoretical predictions indicate that high dust resistivity limits ESP performance.

EPA has completed work to determine the electrical conduction mechanisms in fly ash at high temperatures (730°F).[7,8] Work in this area is being extended to low temperatures. One outcome of this work has been the demonstration of sodium as a potential conditioning agent to reduce fly ash resistivity. EPA has evaluated and published reports on conditioning agents such as SO_3 and NH_3.[9,10] Conditioning appears to be a promising solution to retrofit type problems but not for new installations. Conditioning will not be a solution if it causes adverse environmental effects. EPA will conduct further tests to assess the total impact of conditioning.

Specially designed charging or precharging sections are a possible means of improving the collection of fine high resistivity particles. A fundamental study and limited pilot plant work on particle charging was begun in FY-74.

A mathematical model for the design of ESPs was completed in FY-75.[11] This model is in two forms, a design and selection manual for the plant engineer and a programmed computer version for the design engineer. The model predicts well the performance of ESPs down to particle sizes approaching 0.01 microns. Programs currently underway will improve the model by better defining losses due to poor gas distribution, rapping, and reentrainment. These losses are currently handled in the model on an empirical basis.

Wet ESPs offer a solution to high resistivity and fine particle collection problems from some sources. EPA is completing a systems study of wet ESPs which was funded in FY-73. The results of this study indicate that wet ESPs have performance characteristics similar to dry ESPs without resistivity problems. However, cost and other factors limit the application of wet ESPs. Wet ESPs do not appear to be a solution to the problem of collecting high resistivity fly ash.[12]

The broad objective of the electrostatic precipitator improvement program is to develop an ESP of moderate size (SCA < 300 ft^2/1000 ACFM @ 300°F) for high efficiency (> 99%) collection of high resistivity dusts. Such ESPs would have a minimum particle collection efficiency of 90% at about a 0.5 micron particle diameter. This objective is shown in Figure 1. High resistivity dusts are produced from several sources; the largest is combustion of low S coal.

b. Scrubbers - The Environmental Protection Agency, as a part of this R&D program, has tested approximately eight scrubbers of conventional design on a variety of particulate sources.[13] In general, it can be said that the performance or efficiency of a scrubber drops off rather rapidly as the particle size decreases. It can also be said that the efficiency is directly related to the energy consumed by the scrubber.

The broad objective of the fine particle scrubber program is to develop low pressure drop (30-50 cm water pressure drop) scrubber systems capable of collecting at least 90% by mass of particles smaller than 3 microns in diameter. This objective is shown graphically in Figure 2. With the exception of two TCA scrubbers, the performance of all conventional and novel scrubbers tested by EPA can be represented by points along or above the lower line in Figure 2. The TCA scrubbers represented by the circle labelled TCA, appear to perform better at the same pressure drop than other scrubbers.

The major thrust of EPA's scrubber program has been aimed at developing and demonstrating Flux Force/Condensation (FF/C) scrubbers.[14] In an FF/C scrubber water vapor is condensed in the scrubber. When the water vapor condenses, additional forces and particle growth contribute to the particle collection process. When the water vapor or steam is "free," FF/C scrubbers are low energy users. However, when water vapor or steam has to be purchased, FF/C scrubbers require additional energy inputs for efficient particle collection. A rough idea of the energy consumption/performance relationship for FF/C scrubbers is shown in Figure 2. The right hand region is for purchased steam. Note that when steam is free FF/C scrubbers approach the program objective. The questions of how much steam is needed and how much is free are major unknowns at present. The answer to both questions is likely to be source specific. Thus, pilot demonstrations on a variety of sources are necessary to provide required data. One pilot demonstration is presently underway.

The overall efficiency of a scrubber system is determined by the efficiency of the scrubber and the efficiency of the entrainment separator. Recent field data indicate that in some cases inefficient entrainment separator operation is a major cause of poor fine particle collection by scrubbers. EPA has recently completed a systems study of entrainment separators.[15]

c. Fabric Filters - The performance of baghouses has been completely characterized on three sources, two utility type boilers and one industrial boiler.[16,17,18] The data obtained from these tests show that baghouses are relatively good fine particle collectors and their performance is not very sensitive to particle sizes down to at least 0.3 microns. A major advantage of fabric filters is that they will not require increases in size or energy usage for efficient collection of fine particles.

The current purpose in maintaining an R&D program in fabric filtration is to promote increased capabilities and extend the range of applicability in their control of fine particulates. Of the three conventional devices which can collect fine particles, fabric filters have been in industrial service for the longest time, but the least information is known about their operation from a theoretical standpoint. Although the filter is a simple device in operation, there are complex problems in describing it mathematically. The types of analyses used for scrubbers and electrostatic precipitators have not been effective when applied to filters. Perhaps because the filter already has a reputation for efficiency, EPA spending on filtration research over the last few years has been at a lower level than for ESPs and scrubbers. However, a major effort is now underway to produce design equations and mathematical models for gas filtration processes.

Industry can handle most of the filtration problems for sources which are already controlled by fabric filters. Help is presently needed for sources which present new problems and which are of priority interest to EPA. In order to design for new sources, a better understanding of the filtration process must be acquired. The objectives of immediate work in filtration then become:

(1) Understanding of the filtration process.

(2) Application to priority sources.

(3) Achievement of cost/energy effectiveness.

(4) Development and testing of new filter materials which can extend the applicability of baghouses to a broad spectrum of sources.

d. Assessment of the Collectability of Dust - Actual data on fractional efficiency of conventional particulate collectors is sparse. Actual operating data for the optimization of collection efficiency and cost is not readily available. Installation of control equipment is presently based on projections from historical data which has been developed by manufacturers for their own devices and is proprietary. This information is not standardized and cannot be extrapolated to other devices. On-site testing prior to selection is seldom attempted and the possibility of alternative devices is poorly defined.

Several mobile collectors which can be easily transported from source to source and tested are being constructed. A mobile fabric filter and a mobile scrubber unit have been completed and a mobile ESP unit is scheduled to be completed by early 1976. These mobile units are highly versatile and will be used to investigate the applicability of these control methods to the control of fine particulate emitted from a wide range of sources. The relative capabilities and limitations of these control devices will be evaluated and documented. This information, supplemented by data from other EPA particulate programs, will permit selection by equipment users of collection systems that are technically and economically optimum for specific applications.

3. New Particulate Control Technology Development

This is the program area which has become known as New Concepts. As the requirement to collect finer and finer particulate has developed, the cost of conventional control (ESPs, fabric filters, scrubbers) has risen. Since many important collection mechanisms become far less effective on particles less than 1 micron in diameter, conventional devices (except for fabric filters) have become larger or require more energy and thus are more expensive. The objective of new concepts R&D is to develop new mechanisms or new combinations of well studied mechanisms in order to achieve cost effective control of fine particulate. New concepts include any new technology which has not been reduced to practice and may or may not have been previously studied.

Mechanisms utilized by scrubbers and fabric filters are impaction, interception, and diffusion and by ESPs are field and diffusion charging. This combination of mechanisms gives rise to a minimum in efficiency at the 0.2 to 0.5 micron range for conventional devices. Under optimum conditions, this minimum may be greater than 90% for scrubbers and ESPs and greater than 99% for fabric filters. However, under other conditions such as high temperature, high ash resistivity, sticky particulate, and corrosive or explosive flue gases, new concepts specific to a problem will have an advantage.

Most work to date has been directed toward combining electrostatic removal mechanisms with scrubbing or filtration mechanisms. The first area to be developed was charged droplet scrubbing, with a feasibility study at M.I.T. and a pilot demonstration at TRW on a Kaiser coke oven.[19] Electrostatics and filtration are being studied at both Battelle Northwest and Carnegie-Mellon; the former with bed filters, the latter with baghouses. At least two new concepts, a ceramic membrane filter and a magnetic fiber bed, are oriented toward cleanup of high temperature gases (1000-2000°F). Other new concepts being studied are foam scrubbing and pleated cartridge filters of a novel material. Most new concept work is in the early stages of development so that no demonstration data is available. The TRW charged droplet scrubber is currently being demonstrated and will provide an indication of possible technology advances. EPA has thus far evaluated about 40 new concepts: of these 9 have been selected for funding.

4. New Idea Identification, Evaluation, and Technology Transfer

This area is called for convenience the Novel Devices Area. It includes in addition to Novel Device evaluation and testing, a program aimed at soliciting, stimulating, and identifying new ideas for fine particulate control.

As a part of this latter objective EPA has planned and sponsored four symposiums and two seminars aimed at fine particle control. EPA also has funded a literature search aimed at identifying new technology in foreign countries (Japan, Canada, Russia, and Australia).

Devices or systems based on new collection principles or on radical redesign of conventional collectors are sometimes offered by private developers. Under this program area all such novel devices will be reviewed and if promising will be evaluated for performance and related cost. It is intended that those showing promise of high efficiency fine particle collection at reasonable cost, if necessary, be further developed or demonstrated.

More than 30 novel particulate devices have been identified. About half of these have been of sufficient interest to justify a technical evaluation. To date 10 devices have been either field or laboratory tested:

Braxton-Sonic Agglomerator
Lone Star Steel - Steam Hydro Scrubber
R. P. Industries - Dynactor Scrubber
Aronetics - Two-Phase Wet Scrubber
Purity Corporation - Pentapure Impinger
Entoleter - Centrifield Scrubber
Johns-Manville - CHEAF
Rexnord - Granular Bed Filter

Air Pollution Systems - Electrostatic Scrubber
Air Pollution Systems - Electrotube Scrubber

Of the devices tested, the Lone Star Steel Scrubber gave the highest efficiency on fine particulate, but it is also a high energy user.[20] It can use waste energy, when available. The Aronetics Scrubber is similar to the Lone Star, but was not as efficient. In a field test the CHEAF had an overall mass efficiency of 95% but maintained the efficiency down to about 0.3 microns. The APS electrostatic scrubber was equal in fractional collection efficiency to a venturi scrubber using 2-1/2 times as much power. Results of the APS electrotube have not been received. None of the other devices tested had acceptable fine particulate collection efficiencies.

5. High-Temperature/High-Pressure Particulate Control

This program area was added in FY-75 as a result of the critical particulate and fine particulate collection problems associated with the advanced energy processes. The broad objective of the high-temperature, high-pressure program is to develop the particulate collection devices which are needed to ensure the environmental acceptability of advanced energy processes. However, because the requirements of such energy processes are as yet unknown, EPA has established a near term (18-24 months) objective of developing the fundamental information on the mechanics of aerosols at high temperatures and pressures necessary to determine the most logical path for high-temperature, high-pressure particulate collection research and development.

The state-of-the-art of high-temperature, high-pressure particulate collection is very unclear. There is no clear specification of the degree of particulate collection needed by advanced energy processes. Also, there are no reliable data for the performance of the particulate collection devices proposed by various companies; e.g., granular bed filters and high pressure drop cyclones. There are few data, correlations, or verified theories that can be used to predict the performance of particulate collection devices at elevated temperatures and pressures.[21]

EPA, through FY-75 funded contracts, is conducting research to: determine the feasibility of high-temperature, high-pressure ESPs; determine the effects of high-temperature, high-pressure on basic particle collection mechanisms (literature search funded in FY-75, experimental study funded in FY-76); and determine the estimated particulate cleanup requirements of the proposed new energy processes. EPA, as part of the advanced energy processes program, is looking at granular bed filters (EXXON miniplant) and high pressure drop cyclones (Consolidated Coal). As part of the novel device program previously mentioned, EPA is attempting to evaluate either or both the REXNORD or CPC granular bed filters.

6. Accelerated Pilot Demonstrations

Little attention will be given to this program area since it was covered in each of the preceding sections. Suffice it to say that EPA has currently funded three pilot scale demonstrations and should fund at least two additional ones in FY-76. Although these demonstrations are demonstrations of technology only and are "pilot scale," it has been customary, where possible, to put them on a small source at full scale and thus accomplish a complete process control demonstration.

PROJECTION

Program priorities reflect the increasing importance of coal as a utility fuel in the sense that it will continue over the near term to be the major energy source for the production of electrical power. Research currently underway will determine the effects on particulate control requirements of such new processes as fluid-bed combustors and coal gasification combined cycle plants. In addition, this research effort will attempt to define the applicability and environmental acceptability of agents used for chemically conditioning fly ash for resistivity modification.

As cited above, the present program is aimed at demonstrating fine particulate control technology which will be generally applicable to a broad spectrum of stationary sources both industrial and utility related. To this end the capabilities of conventional equipment have been defined and design and performance models are being developed and perfected.

New concepts and novel device evaluations must continue and order-of-magnitude improvements in conventional equipment must be sought so that environmental quality will not be sacrificed under the guise of economic salvation.

INTERAGENCY PARTICIPATION AND RESOURCE ALLOCATION

A major portion of current EPA efforts to develop fine particulate control technology is being supported by interagency supplemental energy funds. Prior to FY-74, however, this effort was entirely supported by EPA program funds. All current interagency funded work in this area is being conducted in-house and under contracts administered by EPA.

As previously mentioned, EPA and its predecessor organizations have been involved in the development of particulate control techniques since 1958. Since its formation EPA has sponsored a major R&D effort in this control area. EPA's base program was augmented by interagency energy supplemental funds in FY-74, and currently these funds account for about 90 percent of the resource allocations. The total resource allocations for FY-74 through FY-76 are as follows ($ x 10^6):

	Base	Interagency
FY-74	2.14	1.25
FY-75	3.91	1.50
FY-76	0.50	4.16

CONCLUSIONS

It can be concluded that adequate control of emitted submicron particulate matter is presently possible but not broadly applicable to a wide variety of sources including utility sources.

Highly efficient electrostatic precipitators installed on sources whose dust properties are such that they lend themselves to electrostatic collection can currently be effective in controlling fine particles. Additional R&D is needed however, to improve the performance of precipitators on particulate whose electrical resistivity is too high and on particulate in the size range of 0.1 to 1.0 microns. This size range is quite important since it is the most optically active and causes atmospheric haze and thus visibility problems. Techniques which either enhance charging or selectively charge fine particles are currently being sought by R&D programs of EPA's Industrial Environmental Research Laboratory in North Carolina (IERL-RTP).

Conventional scrubbers are not very efficient collectors of fine particles. Current R&D efforts to improve scrubbers are directed toward more efficient utilization of the energy applied to a scrubber system, and toward taking increased advantage of condensation and other physical phenomena which affect to some degree the performance of all scrubbers.

The state-of-the-art and the requirements of high temperature and pressure particulate collection associated with the advanced energy processes are very unclear. Also, there are no reliable data for the performance of the particulate collection devices proposed for the various advanced processes, and there are few correlations or verified theories which can be used to predict performance at elevated temperatures and pressures. Much research and development remains to be done to insure the environmental acceptability of these new processes.

So far only four novel devices have been tested and found to be good collectors of fine particulate. Many more device tests are planned, and a number of new and different concepts, such as ceramic membrane filters, electrostatic fabric filters, and foam scrubbers, are being investigated on a laboratory scale. One new concept, the charged droplet has been preliminarily demonstrated to be a good collector of fine particles. It is hoped that several of the devices and concepts currently under consideration by EPA's IERL-RTP will ultimately result in the demonstration of new and economically attractive processes for the control of all emitted particulate matter.

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Figure 1. - ESP Capital Cost vs. Computed Performance curves at 40 NA/CM^2 Temperature - 300°F

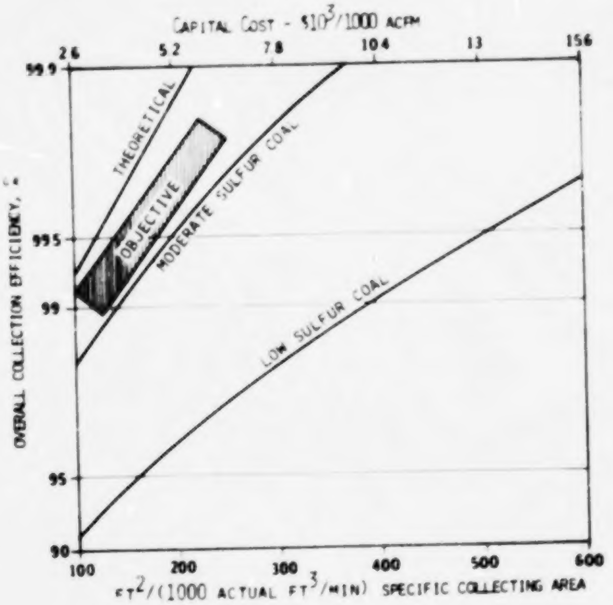
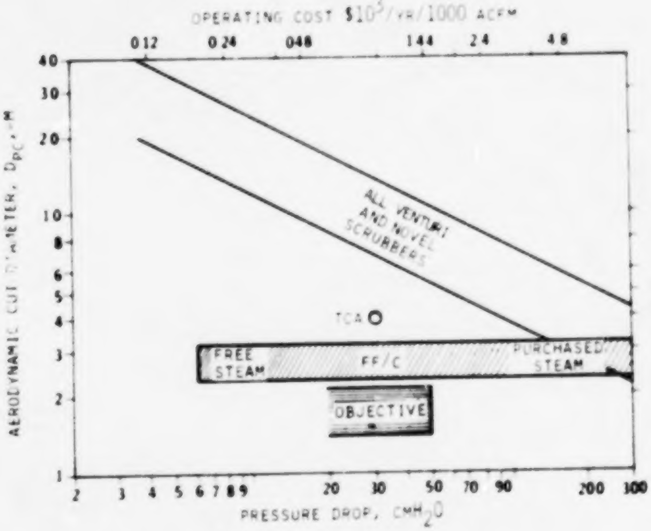


Figure 2. - Scrubber Operating Cost vs. Aerodynamic Cut Diameter

Assume Power Cost 2.5¢/KWHR
8000 hrs. Operation per year



CONTROL OF WASTE AND WATER POLLUTION FROM FLUE GAS CLEANING SYSTEMS

Julian W. Jones
U.S. Environmental Protection Agency
Industrial Environmental Research Laboratory
Research Triangle Park, North Carolina

A major consideration inherent in plans for installing a flue gas cleaning (FGC) system is the necessity for disposing of or utilizing the by-products. This is true for all coal-fired boilers, especially those with flue gas desulfurization (FGD) systems. Application of FGD systems in the United States is accelerating; the majority of these are lime/limestone wet scrubbing systems which produce a calcium/sulfur by-product. Because of environmental and economic concerns related to the disposition of this FGD waste, there have been considerable governmental and industrial research, development, and demonstration activities. Modest EPA efforts in this area were begun in the late 1960's in support of the limestone scrubbing program. In late 1972, major research and development (R&D) efforts were initiated; these efforts were described by the author in a previous paper(1). In late 1974, plans were formulated to greatly expand these R&D efforts as part of EPA's Energy Research Program. These efforts were aimed at determining pertinent environmental parameters, reducing costs, investigating alternative strategies, and encouraging by-product usage. Although the major emphasis in these new efforts was on FGD wastes, they involved consideration of overall power plant waste and water problems, including the disposal and utilization of coal ash. For this reason, the new program was entitled "Control of Waste and Water Pollution from Flue Gas Cleaning (FGC) Systems." In this paper, the program will be referred to as the FGC Waste and Water Program.

The FGC Waste and Water Program, developed in Fiscal Year 1975, consists of the expansion and/or extension of four existing projects and the addition of twelve new projects. Each of the projects is listed in Table 1; the contractor or agency performing the project is listed, along with funding by Fiscal Year.

It is important to note that ten of the sixteen projects in the FGC Waste and Water Program, are being conducted under Interagency Agreements; seven of the ten are with the Tennessee Valley Authority. Approximately half of the funding in Fiscal Year 1975 was used for these Interagency Agreements, which cover a broad spectrum of project types and make up an indispensable part of the program. These are described below along with the other projects in the FGC Waste and Water Program.

PROGRAM DESCRIPTION

The objectives of the FGC waste and water program are to evaluate, develop, demonstrate and recommend environmentally acceptable, cost-effective techniques for disposal and utilization of FGC wastes, with emphasis on FGD wastes, and to evaluate and demonstrate systems for maximizing power plant water reuse/recycle. The projects, all of which are briefly described below, in general, fall in one of five main categories--(1) environmental assessment of FGC waste disposal, (2) disposal economics, (3) alternate disposal methods, (4) utilization of wastes, and (5) overall power plant water use.

1. Environmental Assessment of FGC Waste Disposal

FGC Waste Characterization, Disposal Evaluation, and Transfer of FGC Waste Disposal Technology (The Aerospace Corporation) - This is a broad-based study to (1) identify environmental problems associated with FGC waste disposal by comparing FGC waste chemical/physical characteristics with current, proposed, or potentially applicable environmental standards; (2) assess current FGC waste disposal methods, including feasibility, performance, and costs--by conducting laboratory studies of wastes, providing engineering support and conducting chemical/physical analyses for the Shawnee field evaluation (see below), evaluating other available data, and conducting engineering cost studies of disposal methods; (3) make recommendations regarding alternate disposal approaches based on (1) and (2); and (4) assemble, assess, and report all FGC waste-related R&D activities in EPA, TVA, and private industry.

Formal reports on the Shawnee field evaluation are planned annually; integrated R&D reports of government and industry activities are planned annually; technical papers will be presented approximately every 18 months at EPA FGD symposia. Earlier results from this study have been reported.(1,2,3) The first annual integrated R&D report, to be released in early 1976, will summarize the results from all the projects described below.

Shawnee FGD Waste Disposal Field Evaluation (TVA/Aerospace) - Under this program, the Chemfix, Dravo, and IU Conversion Systems (IUCS) processes for chemical fixation of scrubber wastes are being evaluated in three separate disposal ponds. Untreated lime and limestone wastes are placed in two additional ponds. Leachate, run-off and ground water samples as well as core samples of the wastes and soil are being collected and analyzed to evaluate environmental effects. Both Aerospace and TVA are performing selected analyses; Aerospace is responsible for data evaluation and reporting. Future plans call for evaluation of other disposal approaches, including gypsum disposal. The first formal report on this project will be released in early 1976.

Louisville Gas and Electric Evaluation of FGD Waste Disposal Options - This project includes laboratory studies of non-chemical and chemical (fixation) processes for stabilization of scrubber sludge using carbide lime and commercial lime scrubbing wastes; samples will be mixed with fly ash alone or fly ash and one of several additives (e.g., Portland cement). Results of testing of the stabilized samples will be used to determine those mixtures to be field tested. The field studies include (1) small-scale (about 19 cubic meter) above-ground impoundment tests in which leachate, run-off and physical stability tests of unstabilized and stabilized waste material will be conducted and (2) larger scale (about 76 cubic meter) landfill tests in which leachate migration, run-off, and physical stability tests of unstabilized and stabilized waste material will be conducted.

An interim report will be issued after completion of the laboratory (and part of the field) studies, sometime in the fall of 1976. The final report is expected to provide significant information on the environmental acceptability of several scrubber waste disposal methods. The project is expected to be completed by the summer of 1977.

Lime/Limestone Wet Scrubbing Waste Characterization (TVA) - This project consists of efforts to (1) characterize waste materials from the Shawnee facility and correlate the physical/chemical properties of the materials with the scrubber operating conditions; (2) characterize waste materials from other (full-scale) facilities and correlate properties with scrubber operating conditions; and (3) suggest, if feasible, a means of controlling waste characteristics to improve disposal/utilization economics. The Shawnee studies are expected to be completed in the spring of 1976.

Lab and Field Evaluation of 1st and 2nd Generation FGC Waste Treatment Processes (Corps of Engineers) - This project involves laboratory and field studies to evaluate current commercial (1st generation) and new, not yet commercial (2nd generation) processes for treatment of several industrial wastes, including FGC wastes. The 1st generation processes will be evaluated through laboratory leaching column studies, physical testing of samples of several chemically treated FGC wastes, and small field studies of selected treatment processes. (Initial efforts in this project are similar to the Aerospace studies of treatment processes, except that additional commercial processes are being evaluated.) In addition, visits will be made to existing full-scale disposal sites for complete evaluation (including soil coring) of current disposal. The 2nd generation processes will be restricted to those which are chemically and operationally defined. Candidate processes will be screened via economic analysis, physical testing, and resistance to pollutant leaching. Up to five processes will be selected for comprehensive evaluation similar to that conducted for the 1st generation processes.

An interim report on physical testing and leaching tests of the 1st generation processes will be released in early 1976; an update of this information will be presented at the EPA FGD symposium in March 1976. Final reports on the 1st and 2nd generation studies are expected in mid-1977 and mid-1978, respectively.

Characterization of Effluents from Coal-Fired Power Plants (TVA) - This project involves efforts to (1) characterize and quantify the chemical parameters of coal pile drainage; (2) assess the physical/chemical composition of ash pond effluent after adjustment of pH to meet effluent standards; (3) determine the sampling and analyses necessary for an adequate ash pond monitoring program; (4) assess the effects of coal ash leachate on ground water quality; and (5) evaluate effects of chlorinated effluent in the discharge canal from once-through cooling systems. The final report is planned to be released in late 1978.

Ash Characterization and Disposal (TVA) - This project involves efforts to (1) summarize and evaluate existing data on the characteristics of coal ash and ash effluents from studies made by TVA and others; (2) perform chemical and physical analyses on coal, coal ashes, and ash effluents to characterize these materials as a function of variation in boiler design/operation, and coal type; (3) evaluate various methods for disposal/utilization of fly ash; (4) summarize information on methods of ash sluice water treatment for reuse; (5) conduct conceptual design studies of dry and wet ash handling systems; and (6) recommend the most promising systems for ash handling and disposal/utilization. The final report on the project is planned for January 1979.

Studies of Attenuation of FGC Waste Leachate by Soils (U.S. Army Materiel Command - Dugway Proving Ground) - This study is being conducted to determine the extent to which heavy metals and other chemicals in FGC wastes can migrate through the soil in land disposal sites. At least six scrubber wastes and three coal fly ashes will be tested under this project, which includes the following efforts: (1) physical and chemical characterization of the wastes; (2) leachate studies in columns with the wastes applied to several soil types; (3) long term permeability tests with selected clays; and (4) using data from (1) and (2), identify soil attenuation mechanisms and develop empirical "attenuation coefficients" for specific chemicals. The characterization tests have recently been completed; permeability tests are currently underway. The final report for the project is expected to be issued in mid-1977.

FGD Waste Leachate-Liner Compatibility Studies (Corps of Engineers) - This program is being conducted to (1) determine the compatibility of 18 liner materials with FGD wastes; (2) estimate the service life of the liners, and (3) assess the economics involved with purchase of various liner materials. At least 18 materials have been selected for tests in exposure cells designed to simulate a depth of sludge/liquor of at least 6 meters. These include admixed materials (e.g., soil cements), flexible materials (e.g., polyvinyl chloride), and sprayed-on materials (e.g., asphalts). The materials will be subjected to physical tests to determine whether exposure (for up to 24 months) to FGD wastes causes liner material deterioration. The final report for this project is expected to be issued in the fall of 1977.

Establishment of Data Base for FGC Waste Disposal Standards Development (SCS Engineers) - This project includes efforts to: (1) establish criteria necessary to evaluate FGC waste disposal options; (2) compile any proposed or existing standards/regulations potentially applicable to land disposal of FGC wastes; (3) evaluate the impact of applying these standards/regulations; (4) identify one or more prototype standards for standards/regulations. This effort is expected to be completed by late 1976; however, these initial results are expected to require subsequent updating.

2. FGC Waste Disposal Economics

Conceptual Design/Cost Study of Alternative Methods for Lime/Limestone Scrubbing Waste Disposal (TVA) - In this study several FGD waste disposal methods and FGD system design/operation premises will be selected for detailed economic evaluation. Alternatives will very likely include variations in mechanical dewatering equipment, treatment (e.g., oxidation to gypsum, chemical fixation), and ultimate disposal (e.g., ponding, landfill). The final report on this effort is expected in mid-1977.

3. Alternate Disposal Methods

Evaluation of Alternative FGD Waste Disposal Sites (A.D. Little) - This program is being conducted to identify, assess, and demonstrate, on a pilot scale, alternate FGD waste disposal methods (other than local ponding and landfilling). The initial effort, currently near completion, consists of an evaluation and assessment of the compatibility, capability, and adequacy of deep and surface coal mines, oceans and other potential disposal sites for handling and disposal of untreated and/or chemically treated FGD wastes. Although environmental effects and operational safety are major initial considerations, the assessment also includes an economic study of the alternate methods and a study of applicable Federal and state regulations. Based on the initial efforts, recommendations and conceptual designs for the pilot demonstrations will be made.

The pilot demonstrations, expected to get underway later in 1976, will be conducted at a scale such that design data for full-scale operations can be obtained. The mine study, consisting of tests on small plots at an existing coal mine, will include monitoring for pollutants, characterizing pollutants, identifying limits of physical/chemical characteristics of the wastes, and waste/mine interactions. The ocean study, consisting of tests in a tank which can simulate the ocean environment, will include settling and dissolution characteristics and, in general, any parameters which would stress the ecosystem.

4. FGC Waste Utilization

Gypsum By-Product Marketing Studies (TVA) - A preliminary study conducted by TVA during early 1974 indicated the possibility that production and sale of abatement gypsum might offer a substantial economic advantage over FGD waste disposal. These new studies include a thorough economic evaluation of gypsum producing processes (e.g., Chiyoda, carbon absorption, $CaSO_3$ oxidation) and a detailed U.S. marketing study of abatement gypsum for wallboard. A report on this study is expected in mid-1976. Future plans include studies of abatement gypsum for use in Portland cement manufacture.

Lime/Limestone Scrubbing Waste Conversion Pilot Studies (M.W. Kellogg) - This project involves a cost-shared contract (under negotiation) to conduct pilot studies of two key process steps in the "Kel-S" process for conversion of lime/limestone scrubbing waste to elemental S with recovery of the Ca in the waste as $CaCO_3$. The effort includes (1) reduction of lime/limestone waste to CaS in a continuously rotating kiln, (2) dissolution of the kiln-produced CaS to $Ca(HS)_2$ using H_2S from the Ca recovery unit, and (3) recovery (precipitation) of the Ca as $CaCO_3$, using CO_2- rich gas (available from the drying kiln), with simultaneous release of H_2S, which can be converted to elemental S in a Claus plant. Design data will be generated to allow scale-up to a large (prototype) test unit. Assuming successful pilot testing and reasonable economics, this process would present a viable alternative to lime/limestone scrubbing waste disposal. The project, expected to get underway soon, will last approximately eleven months.

Fertilizer Production Using Lime/Limestone Scrubbing Wastes (TVA) - This project involves the use of lime/limestone scrubbing wastes as a filler material and source of sulfur for fertilizer. This study is a continuation/expansion of previous bench-scale laboratory production tests and small field plot application tests with rye grass. TVA will (1) conduct pilot plant fertilizer production tests using lime/limestone scrubbing wastes, (2) conduct tests of compatibility factors involved in storage and mixing of this fertilizer material with conventional fertilizer, (3) conduct field plot tests using fertilizer from the pilot plant, (4) conduct economic/marketing studies, and (5) determine the amounts of trace and/or toxic elements in this fertilizer and compare them with those in conventional fertilizer. The pilot plant production and storage/compatibility tests are expected to be completed by the spring of 1976.

5. Power Plant Water Use

Assess/Demonstrate Power Plant Water Reuse/Recycle (Radian) - This is a study to minimize water use and wastewater discharges from coal-fired power plants. The study consists of six tasks:
(1) Plant selection and characterization--selection of three or four plants for detailed analysis; collection of data on make-up, process, and effluent waters, plant design, operating modes, coal composition and climate for each plant. (2) Process model preparation--preparation of computer models to simulate make-up, process, and effluent water streams, and chemical equilibria of the processes for each plant selected for study. (3) Simulation of existing plant operation--verification of computer models by comparing existing plant chemical and operating data with model-predicted data.
(4) Assessment of recycle/reuse options--formulation of several options to minimize water requirements and discharges for the plants selected for study; evaluation of at least one option (via

process simulation) for each plant. (5) Cost estimates--preparation of capital and operating cost estimates for each viable water recycle/reuse option. (6) Recycle/reuse assessment report--presentation of program results, including recommended recycle/reuse options for each of the plants studied. Current plans call for completion of this effort by July 1976, followed by pilot plant testing of one or more recycle/reuse options.

FUTURE PLANS

The main thrust of future activities under the FGC Waste and Water Program is continuation of the efforts described above. In summary, this means that the environmental assessment and economic efforts will be pursued to logical conclusions, and that development of promising FGC waste disposal/utilization alternatives and power plant water use technologies will also be pursued. However, three new projects, which are described below, have been included in the Fiscal Year 1976 program plan. The projects generally fall in the category of FGC waste disposal/utilization alternatives.

Dewatering Principles and Equipment Design Studies - This project will consist of (1) an examination of current dewatering equipment design principles to determine their applicability to FGC wastes; (2) laboratory settling and other tests to determine the behavior of FGC wastes as a basis for dewatering equipment design studies; (3) analytical dewatering equipment design studies based on FGC waste behavior; and (4) laboratory bench tests of dewatering equipment design concepts. Further testing of the concepts developed may be conducted if there is sufficient interest expressed by private industry.

Use of FGD Gypsum in Portland Cement Manufacture - This project will consist of the following efforts: (1) laboratory and operational equipment tests at a Portland cement manufacturing plant to determine the acceptable range of variability in the FGD gypsum quality, as well as other potential operational problems; (2) laboratory and operational tests of other uses of FGD gypsum (e.g., road base material) in the Portland cement industry; and (3) a test program involving full-scale FGD equipment at a coal-fired utility power plant and a full-scale Portland cement manufacturing facility.

FGD Waste/Fly Ash Beneficiation Studies - This project will consist of the following efforts: (1) a conceptual design/cost study of a proprietary process for producing sulfur, alumina (for aluminum production), and dicalcium silicate (for cement production) from FGD waste and fly ash (and/or clay), including the development of a preliminary process design and an estimate of capital and operating costs to determine the economic viability of the process; (2) assuming favorable economics, a bench-scale laboratory investigation to determine probable ranges of operating conditions for each of the major processing steps and to determine probable yields and purity of products; (3) assuming a viable process, possible pilot scale testing to obtain design data for large-scale equipment.

CONCLUSIONS

The FGC Waste and Water Program described herein is a comprehensive program designed to reduce the environmental and economic impact of power plant waste and water pollution controls. Results from efforts under this program will provide alternative strategies which can be applied to a fairly broad range of power plant situations. However, application of the results could be strengthened and broadened if additional funding were applied to the pilot/demonstration phases of several projects. Suggested sources of these funds include private industry, the Electric Power Research Institute, other government agencies, and EPA itself.

I feel that it is desirable that this program continue with substantial funding over the next several years because this program, like others in the environmental area, sponsors research and development for which there is, at least initially, little or no financial incentive to private industry. More importantly, results from this program can accelerate the increasing use of domestic coal supplies in fossil fuel-fired power plants; this is an important part of the nation's energy objectives.

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Table 1. - Projects in FGC Waste and Water Program

Project Title	Contractor/Agency	Funding, $1000 Prior to FY 75	FY 75	FY 76	FY 77-80 (est.)	Totals
FGC Waste Characterization, Disposal Evaluation, and Transfer of FGC Waste Disposal Technology	The Aerospace Corporation	596	500	Contracts Under Negotiation See Totals Below	See Totals Below	See Totals Below
Shawnee FGD Waste Disposal Field Evaluation	Tennessee Valley Authority	(205)[1]	(250)[1]			
Louisville Gas and Electric Evaluation of FGD Waste Disposal Options	Louisville Gas and Electric Company (Subcontractor: Combustion Engineering)	0	750			
Lime/Limestone Wet Scrubbing Waste Characterization	Tennessee Valley Authority	0	40			
Lab and Field Evaluation of 1st and 2nd Generation FGC Waste Treatment Processes	U.S. Army Corps of Engineers Waterways Experiment Station	110	325			
Characterization of Effluents from Coal-Fired Power Plants (Waste and Water only)[2]	Tennessee Valley Authority	0	300			
Ash Characterization and Disposal	Tennessee Valley Authority	0	300			
Studies of Attenuation of FGC Waste Leachate by Soils	U.S. Army Materiel Command Dugway Proving Ground	75	300			
FGD Waste Leachate-Liner Compatibility Studies	U.S. Army Corps of Engineers Waterways Experiment Station	0	100			
Establishment of Data Base for FGC Waste Disposal Standards Development	SCS Engineers, Inc.	0	150			
Conceptual Design/Cost Study of Alternative Methods for Lime/Limestone Scrubbing Waste Disposal	Tennessee Valley Authority	0	100			
Evaluation of Alternative FGD Waste Disposal Sites	Arthur D. Little, Inc.	0	250			
Gypsum By-Product Marketing Studies	Tennessee Valley Authority	0	100			
Lime/Limestone Scrubbing Waste Conversion Pilot Studies	M. W. Kellogg Company	0	92.4			
Fertilizer Production Using Lime/Limestone Scrubbing Wastes	Tennessee Valley Authority	0	110			
Assess/Demonstrate Power Plant Water Reuse/Recycle	Radian Corporation	0	200			
Dewatering Principles and Equipment Design Studies Use of FGD Gypsum in Portland Cement Manufacture FGD Waste/Fly Ash Beneficiation Studies	Contractor Selection Pending	0	0			
	Totals	781	3617.4	2549	4685	11,632.4

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[1] Funds for this project included in Shawnee lime/limestone scrubbing project funds, therefore not included in program totals.

[2] This project also includes gaseous emission characterization efforts; additional funds (not shown here) are provided for those efforts.

DISCUSSION FOR FLUE GAS TECHNOLOGY SESSION

Question: In regard to the sulfur removal in flue gas and desulfurization processes, is there any information and comparison between sulfate ambient air levels, estimated in the vicinity where the plume hits the ground, between a flue gas desulfurization plant, and say, one that just has good particulate clean up? Are there any ballpark estimates, ranges of economics that are involved in flue gas desulfurization, NO_x controls, and fine particulate control, all put together, say, for a thousand megawatt plant?

Panel Response: All the data on the subject is not in yet, but one has to remember that the present theory regarding the high levels of sulfates in the Northeast portion of the country is based on long-term transport and transformation of SO_2. In other words, SO_2 is the major precursor to sulfates, at least insofar as present theory is concerned.

Obviously, a flue gas desulfurization system that would control 80 or 90% of SO_2 emissions would have a significant effort, if the theory is correct, on sulfate emissions. Emissions also include small releases of calcium sulfite, calcium sulfate, and lead sulfate. The people at the Halifax Plant indicate that the sulfates there were really acid sulfates, uric acid, ammonium sulfate, others that are quite acidic; whereas calcium sulfite and calcium sulfate, relatively neutral salts, are probably not even sulfates of concern. These comments were further reinforced by other panel members.

Our studies do indicate that when one considers the total potential sulfate problem, that the amounts of primary sulfate, which may be generated by FGD systems is very small compared to the amount of sulfate one would get, both primary and secondary, from an uncontrolled unit. In summary, FGD plays a vital part in not only reducing SO_2 but potential sulfate as well.

In regard to the economics, all the currently available FGD systems fall into a capital cost range of $60 to $100 per kilowatt, or approximately 3 to 6 mills per kilowatt hour. As far as spending costs are concerned, lime, limestone, magnesium oxide would fall on the lowest side of that range. Catalysts and Wellman double alkali would also fall between low to middle. Some of the more advanced processes would move on out toward the upper range. So, it is difficult to really separate how much the FGD is specifically costing in relation to the other systems which also may remove sulfur. I guess that's about all I can say on it, as far as regenerable FGD.

EPA indicated that in proposals they received for double alkali systems the costs ranged anywhere from $50 to $75 per kilowatt in solid capital costs. TVA developed costs in a conceptual design study for a wide-range of plant sizes and operating conditions. However, the total cost for SO_x, NO_x combined has not been addressed, only SO_x has been studied. The range discussed for an SO_x facility is reasonable based on some of the numbers TVA collected.

The numbers for NO_x and fine particulates are just not available yet. These are in a very sketchy stage of development. The industry does not even know what fine particulate is, much less what it's going to cost to control it.

Perhaps one way around the SO_x problem is to go to a low sulfur or a clean fuel where the sulfur is removed before it's combusted. In this case, if you look at the conventional technologies for removing particulates at this time, those that are applicable, and would be considered state-of-the-art, perhaps, the electrostatic precipitator is the one most commonly considered.

When one goes to low sulfur fuels, the electrical resistivity of the fly ash is increased to a point, where it's made very difficult to collect. There are several ways to remedy this. One is to increase the precipitator's size, i.e., the collector area for 1000 CFM gas free. Where a high sulfur coal might take an SCA or precipitator in the neighborhood of, say, 200, for 99 and a half percent efficiency, to meet the new source performance standard, which is a tenth of a pound per million BTU used.

A low sulfur coal, one say at .5 or .75 percent sulfur, with a high resistivity, would take a precipitator considerably larger. It could be as large as 600 to 1000 SCA. In this case, the cost of that precipitator is going to approach, very closely, the cost of the flue gas desulfurization system. It's going to be somewhere between $50 to $75 per kilowatt.

In summary, there is no definitive answer. The cost of fine particulate control alone can be high, depending on what standards are to be met. For example, at this point in time, a tenth of a pound per million BTU is the emission standard for nuclear plants.

As far as the combustion area, it appears to be fairly economical, relative to some of the other aspects discussed. We had some Economic studies conducted by boiler manufacturers indicating that with using existing coal fired technology for retrofitting a coal-fired boiler, the costs would be of the order of $1 - $2 per kilowatt. For gas-fired boilers, if there are any of those in the future, the costs would be of the order to $7.50 per kilowatt. These costs could even be lower if these characteristics of the unit were included at the time the unit was first bid for construction. The upper range costs are somewhat more difficult to determine. They depend on the assumption as to the effect the technology has on the efficiency of the unit.

Question: The Japanese have some 12 Chiota process units working in Japan, and Gulf Power has a unit that uses dilute sulfuric acids. Could anybody comment on the Chiota Plants? I notice that it's been omitted in the discussion so far.

Panel Response: There is much interest in the Chiota system in Japan, and one reason for that interest is the good reputation Chiota has in Japan. When Chiota says they're going to do something, they do it, and they do it well.

However, there are some problems with costs on the Chiota system. It uses 2 percent sulfuric acid recirculation to adsorb SO_2 which does not have a high affinity for SO_2 adsorption. Because of that, the liquid recirculation rates are, generally, 10 times higher than from a conventional scrubber system using black limestone or another adsorbent.

One other potential problem with Chiota is chlorides. At the Schultz Plant, they have a high blowdown rate to keep the chloride level down, and they also have chloride stress problems.

Question: Would the panel pursue the differences in the flue gas chemistry between a coal-fired furnace with a very efficient electrostatic precipitator and an oil-fired furnace. Include NO_x control also. Is there that much difference in the technology and could this be applied?

Panel Response: Using a very high efficiency ESP, the particulates are taken care of. One of the other major differences is the hydrochloride content of coal as compared to oil and gas. Coal-fired flue gas would probably, therefore, have some different constituents, trace elements and so on, as compared to an oil-fired flue gas. Data in this area is sparse, so until more data is available, conclusions cannot be reached. However, to sum it up, it's particulate removal and chloride problems.

One other one is sulfur content. Generally the oil used there is low in sulfur, usually less than 2 percent; so, that's a level where others try to end up. It makes sulfur scrubbing much simpler and cheaper.

Question: A statement was made that the Wellman-Lord system is commercially available, possibly only in Japan and that it has been applied to oil-fired units. However, the Northern Indiana Public Service Plant seems to be continually pushing back the operation of this system. So, I wonder how the statement that it is commercially available at the present time can be justifiably made?

Panel Responses: That is a conclusion reached following all sorts of testimony heard by EPA with regard to the status of flue gas desulfurization technology, at that time heard from Dayton Power and Gas and others who presented information on technology. On the basis of that testimony, the hearing panel indicated that the one Lord system seemed to be commercially available.

There is an abundance of positive operating data on the Wellman-Lord and the Allied add-on to the Wellman-Lord.that there is a great deal of confidence in that technology. The fact is, the NIPSCO (phonetic) Program will be the first coal-fired application of that technology, anywhere in the world.

As far as the slippages go in plant start-up are concerned, these are not slippages resulting from problems in set-up and debugging. These are slippages in a typical plant construction phase; strikes, late delivery of items, fabrication problems with the delivered items, and so on. The anticipated start of that unit is this spring. It's going to be within two months.

CHAPTER 11

ENERGY CONSERVATION

INTRODUCTION

Energy conservation provides what is, perhaps, the most direct and certain contribution to environmental improvement. Energy which is not consumed, need not be produced, and cannot pollute. Thus, measures which reduce energy consumption through more efficient processes, or by abstention, produce the same advantageous results. In a broader sense, measures which result in more efficient energy processes act in much the same way, that is, reduce energy use with its attendant capacity to pollute. In perhaps a somewhat broader sense, substituting what otherwise would be waste material, for a fuel, also conserves the energy represented by the fuel.

The potential savings of energy use is substantial. The industrial sector consumes approximately 40 percent of the nation's annual energy supply. Approximately half of this, or one fifth of the national total, is devoted to production of process steam. This industrial sector is well suited for application of advanced, more efficient, energy cycles, and the conversion of waste materials.

Advanced energy conversion cycles either increase the efficiency of fuel conversion or use energy sources not requiring the combustion of fuels. Potentially high efficiency processes include: magnetohydrodynamics, high and low temperature gas turbines, thermoionics, and fuel cells. Energy not related to fossil fuels may be derived from solar, wind, geothermal, or thermal ocean gradient sources.

The fuel value associated with a year's generation of waste represents about 12 percent of annual energy consumption. While all waste probably cannot be converted to energy, conversion would serve a second purpose of assisting in the waste disposal.

With whatever fuel is fired, conventional energy cycles produce a substantial amount of waste heat. As an example, electrical power generation cycles operate at thermal efficiencies of 40 percent and less. The heat rejected, known as by-product heat, probably has the greatest near-term potential for energy savings. Longer term options could affect savings by generating electricity as a first step to producing process steam, or by integrating industrial activity at a single location so that various energy levels of working fluid could be used most effectively.

EPA RESEARCH IN EMERGING POWER TECHNOLOGY

Robert P. Hartley
Harry E. Bostian
U. S. Environmental Protection Agency
Industrial Environmental Research Laboratory
Cincinnati, Ohio

INTRODUCTION

Several systems are being developed to increase fuel conversion efficiency in electric power generation. Technologies are also being developed for using solar and geothermal energy for power generation and direct heating. In this paper, we will first review the principal new concepts and their potential environmental problems, and then discuss the EPA research program now being initiated.

The research strategy of the Environmental Protection Agency is to assure that environmental protection measures are developed concurrently, and thus not delay commercialization.

Systems for increasing the efficiency of fuel conversion, commonly referred to as "advanced energy conversion cycles," include magnetohydrodynamics (MHD), high and low temperature gas turbines, thermionics, thermogalvanics, and fuel cells. These cycles may be combined with each other and/or with conventional steam turbine generation to further increase conversion efficiency.

Solar energy conversion presents the possibilities of economical and clean conversion from an essentially unlimited source. Concepts and technologies are rapidly evolving. Included in solar energy sources are direct radiation, winds, and ocean thermal gradients.

Geothermal energy conversion to electricity is already commercialized at one site, operating on dry steam. Most of the potentially exploitable geothermal energy reserves are in hot waters and geopressured brines in the west and southwest.

ADVANCED ENERGY CONVERSION CYCLES

Magnetohydrodynamics (MHD)(1)(2)(3) - Electricity is generated by passing very hot conducting gas (plasma) at very high velocity (near the speed of sound) through an electrode-lined channel between the poles of a superconducting magnet. In an open-cycle system, the gas is that of combustion of coal, oil, or gas. To be most effective, the gas is "seeded" with a metal, such as potassium or cesium, to increase the gas' conductivity. During seed recovery, other combustion-derived air pollutants will probably be removed. Closed-cycle MHD, using a recycled working gas, appears less promising because of heat transfer, corrosion, and abrasion problems with fossil fuels most likely to be used. It may be feasible, however, with nuclear fuels.

Both open and closed-cycle MHD, using fossil fuels, may cause air and water pollution problems similar to conventional power plants, such as particulates, sulfur oxides, nitrogen oxides, and waste heat.

High-Temperature Gas Turbines(4)(5)(6) - Both open and closed-cycle, high-temperature gas turbine generators are under development. In an open-cycle system, the combustion gases are the working fluid, while in a closed cycle, the working fluid is a separate recirculated gas. The technology is directed to increasing efficiencies by developing very high temperatures and materials to withstand them.

The most significant open-cycle exhaust pollutants are nitrogen oxides. Others have been insignificant because very clean, ash-free fuels (gas or oil) must be used to avoid damage to the turbine. The closed system allows a choice of clean working fluids which may have more favorable thermodynamic properties and cause less internal deterioration. However, dirtier fuels may be used, such as coal, with the attendant combustion contaminants. Pollutant emissions would include particulates, sulfur oxides, and nitrogen oxides.

Low-Temperature Gas (Vapor) Turbines(6)(7) - Low-temperature vapor turbines operate as closed systems with low boiling working fluids, such as ammonia, propane, and other organic gases. These cycles are inherently inefficient and must rely upon high efficiency heat exchangers and a large, low-cost, high flow heat source. Low-temperature vapor turbines may be used as "bottoming" cycles, utilizing the residual heat from other higher temperature conversion cycles. Low-temperature cycles may be used in proposed ocean thermal gradient power generation systems, utilizing the temperature difference between the upper warm ocean water and the bottom cold water. They also may be used in low-temperature geothermal systems.

Except in ocean systems, the heat source may cause pollution, such as from geothermal brines or combustion products from the primary system. Spills of working fluid also pose a potential problem particularly in ocean systems.

Thermionics(2)(8) - Thermionic cycles convert heat directly into electricity. Electrons escaping from a heated substance (the cathode) collect on a nearby cooler substance (the anode). The electrons are then transmitted through a load back to the cathode. Thermionic converters can be used as "topping" units for conventional steam-electric systems, operating on the initial heat before it is used for steam production.

Pollution from thermionic generation will derive from fuel combustion with its attendant air emissions, types and concentrations dependent upon the fuel and combustion process. Waste heat may also be significant.

Thermogalvanics(8) - Two dissimilar metals, joined and heated at their junction, cause electrons to flow from one to the other. If a load is placed between them, a net current around the circuit results. Conversion efficiencies for thermogalvanic systems are low, requiring a low-cost heat source. The efficiencies are limited principally by the metals combination. Pollution from thermogalvanic generation, like most other generation methods, would depend on the fuels used for heating.

Fuel Cells(2)(7) - The fuel cell is a highly efficient system for the conversion of fuel directly to electricity. Most systems are based upon the chemical reaction between hydrogen and oxygen, although fuels other than hydrogen have been used. Widespread commercialization is dependent upon large-scale, low-cost production of hydrogen for that purpose. The hydrogen-oxygen fuel cell operates at low temperature. Its only significant waste product is water; thus, it is one of the cleanest energy conversion methods. The production of the necessary hydrogen may result in significant waste products, however, depending upon the methods used.

GEOTHERMAL ENERGY CONVERSION(9)(10)

Geothermal energy may be available as a heat source where the temperature is high enough at sufficiently shallow depths. Currently, the most promising areas are in the western states and in Texas, Alaska, and Hawaii. All areas except Texas are in, or near, seismically active areas where molten rock is near the surface. Five types of geothermal energy reservoirs are under investigation as useful heat sources: (1) vapor-dominated, (2) liquid-dominated, (3) geopressured, (4) hot dry rock, and (5) magma (molten rock).

The steam from the relatively rare vapor-dominated (dry steam) sources can be passed directly through steam turbine generators, such as at the Geysers, California. Vapor-dominated systems have gas contaminants, the principal one being hydrogen sulfide, the control of which in air emissions is now being researched. Radioactive gases may be a problem. Gases dissolved in the condensed steam and cooling water are also significant. At the Geysers, this water is reinjected. Vapor-dominated systems are characteristically low in dissolved solids. Wells are vented to the atmosphere when they are brought in and when generators are shut down. In addition to entrained contaminants, the accompanying noise can be severe. Mufflers are employed, but apparently have not been entirely adequate.

Although there are no commercially operating, liquid-dominated geothermal systems in the United States, the resource is widespread. Development is progressing rapidly in exploration, and in pilot and demonstration plant design, particularly in the Imperial Valley of California, looking toward power generation, desalination and fresh water supply, and mineral extraction. Lower-temperature liquid-dominated systems can be used more practicably in applications such as space heating and desalting.

Liquid-dominated systems are characteristically very high in dissolved solids content and may be very high in dissolved gases. In power production, flashing to produce steam leaves behind water with even higher concentrations. Desalination results in noxious bitterns. Cooling tower blowdown results in similar wastes. None of these can be discharged to surface waters, so that reinjection appears to be the best alternative at the moment. While reinjection may provide needed recharge to the system and help prevent land subsidence, it may also cause ground-water contamination and solids precipitation and plugging in the reinjection routes. Pretreatment would produce solid wastes from which valuable metals and minerals might be reclaimed. Closed power generation cycles appear feasible for liquid-dominated systems.(6) Such cycles would withdraw the geothermal water, transfer the heat to another closed-cycle working fluid, and reinject the geothermal water to the original formation. Such a system may solve most, if not all, of the waste problems.

Geopressured systems along the Gulf Coast lie at depths up to 10,000 feet. Temperatures are generally well above 150°C and pressures are above 3000 psig. They apparently contain large quantities of methane, a valuable by-product. The relatively great drilling depths required may delay development. Geopressured systems development will encounter much of the same environmental problems as liquid-dominated systems described above. Cycle technology may differ to take advantage of the high liquid pressures in addition to the heat. Gas separation is likely to be an important and profitable adjunct. Whether reinjection will be feasible is not yet known.

Hot dry rock systems will require injection of water to an artificially fractured formation where it will take up heat and be withdrawn for use. The withdrawn water may be relatively clean compared to the above described systems, but this is by no means certain.

Magma systems would utilize the heat of molten rock in volcanic zones where it is relatively near the surface. This may require subsurface heat exchangers. Investigations of these systems are still in the formative stages so that it is conjectural to discuss the resulting environmental problems.

SOLAR ENERGY CONVERSION(8)(11)

Solar energy conversion technology is advancing rapidly, particularly in the area of heating and cooling of buildings. Commonly a "flat-plate collector" is used for absorption of the sun's radiant energy. Water in contact with the flat plate is warmed and recirculated to an insulated storage tank. Similar systems have been designed using air instead of water with storage in a granular solid material such as rocks. Solar energy has been used for a long time for water distillation in water-short areas. Water covers a dark flat surface, is heated and evaporated, condensing on an overlying, sloping, transparent surface, and is collected therefrom for use. The above systems are of little concern as environmental hazards. In solar stills, however, a residual brine may require disposal.

Large direct solar systems for power generation are in conceptual and design stages. Very large collector surfaces may be used to focus the heat at a central boiler station operating a turbine generator. Another possible system is a large array of solar (photovoltaic) cells, converting the radiant energy directly to electricity.

Wind energy, derived from the sun, is also undergoing renewed and fairly rapid development. Development is taking the direction of power generation by windmills, which may have the advantages of low cost and adaptability to small individual applications, but may be unsightly.

Ocean thermal gradients, again derived from the sun's direct energy, are being considered for power production. The upper warm waters would heat and expand a low-boiling point recirculating working fluid, such as ammonia, which would in turn drive a turbine and be condensed using colder bottom waters. A critical factor is the development of a large floating system capable of withstanding the rigors of the open ocean environment. Added to this is the problem of transferring the energy to the point of ultimate use. One concept is to build a hydrogen-producing plant and transport the hydrogen to the point of use as a fuel. As mentioned before, the major environmental concern with ocean thermal gradient utilization is for the possibility for spills of the working fluid.

In comparison to the other systems we have discussed, solar energy conversion is relatively pollution free in concept. Some environmental concerns may be significant, however, such as aesthetics, shading, and land use priorities.

EPA RESEARCH APPROACH AND PROGRAM

The objectives of the EPA research program, now being initiated, will be to (1) monitor on-going developments in each of the technologies, (2) evaluate various alternatives within a technology and identify those which are more environmentally acceptable, and (3) identify and/or develop needed environmental control approaches.

A major contract on advanced cycles is now being negotiated. The overall approach will be as follows. Initially, cycles will be described in detail, environmental impacts evaluated, and the cycles ranked as to priority for further assessment. Appropriate cycle simulation models will then be developed, characterizing various design variations as to process streams and environmental emissions. The models will be used to assess the potential need for and cost/effectiveness of pollution control alternatives. Next, a series of field tests on bench and pilot-scale installations will be used to validate the cycle models. Existing control techniques which can be incorporated into the cycles prior to commercialization will be defined, along with additional work required. A short-term independent assessment of advanced power cycles is already underway by contract with Lockheed-Huntsville. The purpose of this project is to obtain immediate input for planning purposes.

A research contract was awarded in December, 1975, to Wapora, Inc., for an assessment of geothermal energy technology and regulatory constraints. The first phase of the study is to detail regulatory and institutional limitations (including environmental) with respect to development and system operation. The second phase will describe the known geothermal reservoirs, their physical-chemical characteristics, exploitation potential, exploration and development processes, pollutional implications and available control options. Non-pollutional environmental effects will also be described. Future research and development needs will then be enumerated.

The first solar energy project with Lockheed-Huntsville, just underway, is a preliminary description of the various solar energy technologies and environmental impacts to be expected from each. It will identify areas of insufficient information for planning a program and will identify personnel in other organizations who are working on environmental aspects. A second solar energy project will follow which will describe in detail the various technologies, define the anticipated environmental impacts, and identify gaps in the environmental baseline data. On-going research will be described, and areas needing emphasis will be defined.

INTERAGENCY PARTICIPATION

The major development work on new power technology is being supported by other federal agencies, principally the Energy Research and Development Administration (ERDA). In order to be effective, EPA will have to maintain a close relationship with ERDA. Initial contacts have already been made and we expect to develop close cooperation with ERDA.

RESOURCE ALLOCATION

The EPA program in new power technology is a relatively modest one. EPA funding began in FY75, and the total resource allocations projected through FY76 are as follows:

	FY75	FY76
Advanced Cycles	$250,000	$250,000
Geothermal Systems	123,000	99,000
Solar Energy Systems	--	60,000
	$373,000	$409,000

CONCLUSIONS

Development of advanced power generation cycles is in the relatively early stages with magnetohydrodynamics and high temperature gas turbines receiving the most attention. These and other cycles which use fuels are likely to produce wastes similar to those of conventional power generation. However, waste generation of "conventional" pollutants (SO_x, NO_x, particulates, etc.) per unit of production will likely be less because of increased conversion efficiency and improved combustion and waste treatment technology.

Geothermal energy development will result in wastes with high dissolved solids and dissolved gas content. The problems may be so severe that reinjection of geothermal fluids will be the only reasonable method of waste control, even though it too may cause problems. Solar energy conversion is not expected to cause direct waste control problems of great significance, but may have other adverse environmental impacts.

The EPA research program will help to identify and develop technologies and treatment methods that minimize the environmental impacts in the above areas. The direction the program eventually takes will depend upon the particular conversion technologies to be commercialized.

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THE WASTES-AS-FUEL R&D PROGRAM
OF THE
EPA OFFICE OF ENERGY, MINERALS AND INDUSTRY

George L. Huffman
U. S. Environmental Protection Agency
Industrial Environmental Research Laboratory
Cincinnati, Ohio

INTRODUCTION

Solid waste is generated from most all activities: from the farm to the feedlot; from the home to businesses; from mineral extraction operations to all types of industrial manufacturing operations. The use of solid waste as a fuel for energy generation has been practiced for some time in Europe--however, its practice in this country is essentially just beginning. In the U. S., numerous processes are under development which convert the energy contained in solid waste into steam, oil, gas, and electricity. In conjunction with the development of these processes, the USEPA is conducting a broad-based research program to define the environmental problems associated with such development and to develop control technology for the pollution problems thus defined.

The Administrator of EPA is mandated under the 1965 Solid Waste Disposal Act, as amended by the 1970 Resource Recovery Act (PL 91-512), to perform research and demonstrations to develop and to apply new and improved methods for processing and recovering both materials and energy from solid wastes. The Act also requires the study of adverse health and welfare effects of the release into the environment of materials present in solid wastes, as well as methods of eliminating such effects. The Act authorizes EPA to issue contracts and grants for research and/or demonstrations of technologies in the waste-as-fuel area to enable appropriate response to these mandates. EPA is also directed, under the Clean Air Act and the Federal Water Pollution Control Act, to establish performance standards for existing and new sources of pollution based on available technology.

It has been estimated that about 4.5 billion tons (4.1 trillion kilograms) of municipal, industrial, mineral and agricultural solid wastes were produced in this country in 1970 (Ref. 1). Of this amount, about 13 percent has been estimated to represent the dry, combustible fraction, according to one study. Therefore, about 570 million tons (517 billion kilograms) of dry combustible solid waste were discarded in 1970 (Refs. 2 and 3). By way of comparison, a Bureau of Mines estimate arrived at a figure of 880 million tons (800 billion kilograms) as the dry, organic waste generation rate for 1971 (Ref. 4). This latter figure represents an energy equivalent of about 1.1 billion barrels (175 million cubic meters) of oil per year, or about 70 percent of the oil imported that year (Refs. 4 and 5).

The fuel value associated with the 1970 waste stream estimate mentioned above represents a yearly waste of 8.5 quadrillion Btu's (Refs. 2 and 3). This is about 12 percent of the total energy requirement of the United States, which approximates some 70 quadrillion Btu's/year (Refs. 5 and 6). Not all of this combustible solid waste is readily available for use as a fuel, however. Although urban-generated waste may qualify as a fuel because it is available in rather concentrated form at appropriate locations, other kinds of wastes from processing, manufacturing, or agricultural operations are often generated in widely dispersed areas. One study (Ref. 3) found that only about 1.5 to 3.0 percent of the Nation's total energy requirement could be supplied by our solid waste due to its geographical dispersion, assuming plants no smaller than 100 ton-per-day (90,000 kilogram-per-day) capacity could be economically justified. This assumption, given current prices for conventional fuels, may not be valid.

EPA has been involved in furthering the development of major waste-as-fuel technologies in response to its legislative mandate to do R&D on methods which dispose of waste materials in an environmentally acceptable manner. Certainly, one of the best "disposal" options available (potentially best economically and environmentally) is to treat the waste in such a fashion that its energy and material resource values are recovered. That is, why necessarily should we face the difficult environmental control problems associated with the "throw-away" options of improper land disposal or air-polluting incineration of high-Btu wastes?

As early as 1967, EPA began development of several waste-as-fuel processes. Two of the major process options that began to be researched at that time were the CPU-400 System and the Horner and Shifrin Fuel Recovery Process (St. Louis). The tabulation below illustrates some of the salient features of these two processes, along with similar data for two other more-recently-initiated EPA developmental efforts (the Garrett and Monsanto Pyrolysis Processes):

EPA's Grantee (Contractor)	Process Concept
• Baltimore, Maryland (Monsanto Enviro-Chem)	Pyrolyze Solid Waste to Generate Steam and Char (LANDGARD)
• San Diego County, Calif. (Garrett Research)	Pyrolyze Solid Waste to Fuel Oil and Char
• St. Louis, Missouri (Horner and Shifrin and Union Electric)	Burn Solid Waste with Coal at a Steam Power Plant
• (Combustion Power Company, Menlo Park, California)	Burn Solid Waste for Direct Generation of Electricity (CPU-400)

In addition to these four major developmental efforts, EPA is actively engaged in furthering the development of, and in environmentally assessing, several other wastes-as-fuel process options. A new thrust in this area has recently been initiated within EPA's Office of Research and Development (Ref. 7). This recently-initiated research program will be summarized with the aim of providing some insight into program rationale.

WASTE-AS-FUEL PROCESSES

1. Program Objectives and Technical Approach

The principal objectives of the EPA Waste-As-Fuel research program are:

- To allow the tapping of a potential energy resource, as yet essentially unused in the U. S., to help meet our energy needs in an environmentally acceptable fashion;
- To allow the attainment of a more cost-effective system of solid waste management through resource recovery;
- To reduce and control undesirable environmental impacts resulting from waste utilization in various fuel technology operations; and
- To achieve an incremental reduction of pollutant generation and energy consumption from the traditional practices of using virgin resources for fuels and materials production through the substitution of waste-derived fuels and the recycling of resources recovered from waste streams.

If these objectives could be achieved, sufficiently well to spur widespread implementation of the technologies involved, not only would the mounting solid waste disposal problem be alleviated but also part of the Nation's energy conservation goal (of saving prime conventional fuels) would be met.

The technical approach being utilized in the EPA research and development program in waste-as-fuel is aimed at determining how to effect, in an environmentally acceptable fashion, the disposal of industrial, municipal, and agricultural wastes via conversion of their stored energy into useful energy forms (e.g., electricity, fuel gas, fuel oil, char, etc.). The program will produce the technological, economic and environmental assessments of major waste-as-fuel processes under development.

2. Program Discussion

The current EPA program can be subdivided into four major areas of emphasis. These areas are: (1) Assessment R&D (environmental, technical, economic); (2) Waste Co-firing with Coal, Oil, or Industrial Waste; (3) Waste Co-combustion with Sewage Sludge; and (4) Pyrolysis and Bio-conversion Processes.

Work in the first area, in Assessment R&D, features environmental, technological, or economic assessments of waste-as-fuel options. Research in "Assessments" includes a study to acquire pollutant characterization data for the competing waste-as-fuel processes, as well as to develop environmental assessment criteria and proper sampling/analytical techniques. With this data, R&D will begin on assessing the technology available to control air pollution from these processes and on developing needed control technology. Work is also underway, by the Ralph M. Parsons Company of Los Angeles, on performing a comparative technical and economic evaluation of the developing waste-as-fuel processes. Several waste surveys will be conducted by other organizations in an attempt to better define the energy values of selected waste streams, such as those from industry and from demolition operations. To spur the coming together of waste producers (e.g., the cities) and waste users (the power industry for example), EPA has awarded approximately 10 grants to selected municipalities to allow for appropriate planning of waste-as-fuel utilization or conversion facilities. Work will also be done in waste pre-processing. An EPA grant has been awarded to the National Center for Resource Recovery to enable a side-by-side evaluation of existing shredders, air classifiers, etc., to define operating characteristics and efficiency. A state-of-the-art evaluation of other pre-processing techniques for grinding and separating the inorganic and combustible waste fractions will also be performed.

The work in the Waste Co-firing with Coal, Oil, or Industrial Waste area includes finalization of research at the St. Louis Union Electric project. This will center on the identification of potentially hazardous emissions associated with waste co-firing with coal. R&D will continue by Battelle at a small Columbus, Ohio, boiler in which varying ratios of coal-to-refuse will be run--particular emphasis here will be on defining the corrosion rates associated with co-firing. At another site, a comparative evaluation will be made of co-firing waste with coal in tangentially-fired boilers versus stoker-fired boilers; the evaluation will compare process and environmental characteristics of each option. Yet another coal/waste co-firing option will be tested: that of densifying (e.g., pelletizing) the waste and injecting along with lump coal into an industrial-sized stoker-fired boiler.

Two other co-firing options will be investigated: (1) the combustible fraction of municipal solid waste will be double-ground and co-fired along with fuel oil in existing oil-fired boilers (technical and environmental feasibility will thus be determined); and (2) a feasibility study is underway in Hawaii to determine the worthwhileness of co-firing solid waste along with bagasse in industrial bagasse boilers.

Two projects have been initiated in the waste-as-fuel area known as Waste Co-combustion with Sewage Sludge. The first of these projects centers on the utilization of various municipal and industrial wastes (e.g., refuse, tires, wood chips), and/or low-sulfur coal, to combust or incinerate sewage sludge in an existing, full-scale multiple hearth sludge incinerator in St. Paul, Minnesota. The second project involves using the CPU-400 pilot plant to test the process and environmental characteristics associated with co-combusting solid waste and sewage sludge in a high-pressure fluidized bed, the off-gases from which are cleaned upstream of their expansion through a gas turbine for power recovery.

Several projects are underway in the EPA waste-as-fuel area of Pyrolysis and Bio-conversion. The most comprehensive of these is the recently-begun research at the Energy Resources Company (ERCO) in Cambridge, Massachusetts. ERCO, with assistance from MIT, will conduct bench and pilot-scale (500 pounds per hour or 230 kilograms per hour) tests on the pyrolytic conversion of mixed waste to fuel. Work at this environmental test facility will feature the pyrolysis of various mixtures of waste (e.g., refuse, industrial wastes, agricultural wastes) at varying residence times (space velocities) and operating temperatures to define what product ratios (of fuel gas to fuel oil to char) are possible and what environmental consequences may result. The China Lake Naval Weapons Center is conducting bench-scale research for EPA on upgrading (via polymerization reactions) pyrolytic fuel oil/gas to gasoline. Another R&D effort underway in the waste pyrolysis area is that which is being done at the Georgia Institute of Technology: It centers on the concept of disposing of agricultural wastes by having them processed in a portable van containing a pyrolysis reactor which converts the otherwise-wasted material to transportable fuels, such as fuel oil or char. In the biological conversion area, the Army's Natick Laboratories are carrying our bench-scale research for EPA on converting waste cellulose to an ethyl alcohol fuel. The process features the enzymatic hydrolysis of cellulose to ethyl alcohol using glucose as the intermediate step.

3. Program Projection

From the above Program Discussion, it can be discerned that the primary emphasis to date in the EPA Wastes-As-Fuel R&D program has been directed toward the municipal solid waste disposal problem. Municipal waste disposal is one of the more significant waste disposal problems from an environmental standpoint. Consequently, there will be continuing research addressing this problem. Concurrently, however, there will be an increase in EPA research emphasis on other waste streams whose disposal represents a significant environmental problem and whose heat and energy content is worth recovering.

It is projected, therefore, that there will be increasing emphasis in the environmental research areas of heat-recovering industrial and agricultural waste co-combustion with conventional fuels and in the area of industrial/agricultural waste pyrolysis. Multiple-waste co-firing and co-pyrolysis, and mixed waste thermal processing along with fossil fuels, should also receive some emphasis.

In terms of which thermal processing techniques will receive emphasis in the future, the projection is that the use of waste as a supplementary fuel will continue to be researched, as will the waste pyrolysis to clean fuels technique.

INTERAGENCY PARTICIPATION

Through Interagency Agreements, EPA has funded two projects in wastes-as-fuel research. As cited above, these projects involve bench-scale efforts--one by the Navy in the waste pyrolysis area, and the other by the Army addressing the bio-conversion of waste to alcohol concept.

RESOURCE ALLOCATION

Since 1967, a portion of EPA's research budget has been directed toward the waste-as-fuel area. Through FY74, the resource allocation came exclusively through EPA's base program for solid waste research. However, starting in FY75, resources for wastes-as-fuel R&D came primarily from the ORD Office of Energy, Minerals and Industry (OEMI) program--though a portion of the total continued to come from ORD base program. This split is depicted in the following tabulation, a tabulation which shows the total estimated resource allocation in wastes-as-fuel research over the last three fiscal years ($\$ \times 10^6$):

	FY74	FY75 (Ref. 7)	FY76
ORD Base Program	1.0 - 1.5	1.95	0.87
ORD/OEMI Program	--	4.50	3.44
TOTAL	1.0 - 1.5	6.45	4.31

CONCLUSIONS

One estimate shows that as much as 12 percent of the Nation's total energy requirement could come from converting industrial, municipal, and agricultural wastes to usable energy forms such as steam, fuel oil, fuel gas, and electricity. Due to the geographical dispersion of much of this waste, however, perhaps "only" 1.5 to 3.0 percent of our total energy requirement (1 to 2 quads, i.e., 1-2 quadrillion Btu/year) is potentially recoverable from waste. This percentage could well be increased if prices for conventional fuels continue to escalate.

EPA has had a significant R&D program in Wastes-As-Fuel since 1967 under authorities of the 1965 Solid Waste Disposal Act and the Resource Recovery Act of 1970. Over \$20 million has been allocated by EPA for research and development in this area from this early beginning through FY76.

The current EPA research program in Wastes-As-Fuel has four major areas of emphasis: (1) Assessment R&D (environmental, technical, economic); (2) Municipal Waste Co-firing with Coal, Oil, or Industrial Waste; (3) Municipal Waste Co-combustion with Sewage Sludge; and (4) Pyrolysis and

Bio-conversion Processes. Current emphasis is on the municipal solid waste stream since it represents a significant environmental control problem.

The future R&D program within EPA in the Waste-As-Fuel area will emphasize otherwise-polluting industrial and agricultural waste streams and will center on the environmental control aspects associated with co-firing various wastes as supplementary fuels and with pyrolyzing wastes to clean fuels.

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WASTE HEAT UTILIZATION/REDUCTION

Alden G. Christianson
U. S. Environmental Protection Agency
Industrial Environmental Research Laboratory
Cincinnati, Ohio

INTRODUCTION

Our Nation's environmental, energy, and economic considerations are increasingly interdependent. A prime example is the impact that the trends in electrical generation have on the production and management of waste heat.

Electrical energy requirements are projected to be the predominant energy growth factor over the next 30 years. Whereas total energy demand doubled between 1950 and 1972 (Ref. 1), electrical production has doubled every 10 years (about a 7 percent annual increase) over the past 50 years. These trends, which are predicted to continue at nearly the same rate, indicate the increasing role of electricity relative to other forms in meeting our energy demands. In fact, it is estimated that by the year 2000, 41 percent of our energy needs will be supplied by electricity (Ref. 5), compared to 26 percent in 1973 (Ref. 4).

In terms of national energy conversion efficiency, growing demand for electricity plus anticipated continuing increases in transportation uses (as much as 3.5 percent per year) will raise overall conversion losses from about 50 percent in 1970 to almost 55 percent in 1990 (Ref. 2). If such projections hold true, the impact on resource requirements and waste generation will be rather startling. A national decrease in energy conversion efficiency from 50 percent to 45 percent will result in an 11 percent increase in input fuel requirement on a unit Btu basis, i.e., not considering the growth in energy demand. The same efficiency decrease results in a 22 percent increase in waste heat production, again on a unit Btu basis.

For a final comparison, it is interesting to consider both growth rate and magnitude of waste heat production. With electrical demand doubling every 10 years, the predicted heat dissipation from central power sources in the year 2000 is about 72 quads (Ref. 3)--an amount equal to total energy demand in 1970.

In the past, low fuel prices, plentiful supplies of natural gas and oil, and the absence of pollution control regulations limited incentives to use waste heat or pursue more efficient integrated energy systems. The situation has, however, changed drastically in the past 3 years. The costs of natural gas, oil and coal have risen significantly Natural gas is in short supply, and many large utilities and industrial users are being forced to convert to oil or coal. The availability of oil is uncertain because of reduced production in the United States and the political situation in the Middle East. Environmental limitations on SO_x emission have necessitated the installation of scrubbers or the burning of low-sulfur coal. Limits on thermal discharges required that closed-cycle cooling systems or other control measures be built. Finally, the costs of new construction, as well as the cost of capital, have risen considerably. It is estimated that these trends will continue and that the cost of energy will be forced still higher (Ref. 5).

Under current energy costs and availability, waste heat use has a greater potential for economic viability and, therefore, has enhanced potential for producing environmental and energy-related benefits. In terms of energy impact, ERDA (Ref. 3) estimates that almost 13 quads can be saved in the year 2000 if industrial energy efficiency is improved and waste heat is utilized.

PROGRAM DISCUSSION

The Environmental Protection Agency (EPA) has been involved in waste heat reduction and control activities primarily because of its overall mandate to mitigate environmental impact. From an environmental viewpoint, waste heat reduction/utilization offers numerous benefits: (1) reduces quantity of pollutant generation and release, (2) reduces cost of pollution control equipment, (3) offers potential profit which could help offset cost of pollution control, (4) conserves energy resources, and (5) eliminates the overall impact of obtaining, processing and supplying the energy which has been replaced by the "reclaimed" heat.

There are numerous options available for waste heat utilization/reduction, many of which have received attention in EPA's RD&D program. We have focused on 3 options which we feel have good potential for application: (1) utilization of by-product waste heat discharged from conventional industrial and utility plants, (2) generation of by-product electricity in industrial plants; and (3) development of integrated energy production/use complexes which utilize energy more efficiently. The first option uses heat after it has been discharged from a process or facility, while the others involve optimizing the design and management of the process itself to reduce the amount of heat wasted.

1. By-Product Waste Heat Utilization

This option has the greatest potential for near-term (now through 1985) energy savings, and most waste heat applications are based on this approach. The waste heat involved is the conventional, by-product heat rejected to air or water from an industrial process. Typically, it is low-quality heat, such as that available in power plant condenser cooling water which is usually between 10°F and 40°F above incoming water temperature.

A number of direct-use waste heat applications have been investigated to varying degrees--the more promising methods receiving effort toward demonstrating their full-scale feasibility. At pre-energy-crisis fuel prices, the most economically attractive waste heat applications were in agricultural and aquacultural endeavors.

Agricultural demonstrations have shown promise in areas of irrigation, frost protection, undersoil heating, and greenhouse heating and climate control. Greenhouse applications appear most economical, because high-cash-value crops, such as flowers and vegetables, are involved. Refined systems are currently being demonstrated which should result in commercial involvement in 3 to 4 years.

EPA helped support an agricultural project near Eugene, Oregon, from 1968 to 1973. Cooling water from a pulp and paper mill was used to provide spring frost protection, irrigation, crop cooling in the summer, and soil heating. The project was most successful in providing spring frost protection and in increasing crop yields in a greenhouse heated by underground pipes.

A second demonstration project partially funded by EPA is now underway at the Sherburne County power plant in Becker, Minnesota. Heated water from the condenser cooling loop of the 2-unit, 1400 MWE plant will provide soil and air heating for a one-half acre greenhouse, an operation that normally consumes 25,000 gallons of oil or 3.5 million cubic feet of natural gas a year. If the experiment is an economic success, a commercially developed 100-acre greenhouse complex could be in operation by 1985, at a savings of 5 million gallons of oil or 700 million cubic feet of gas.

The Tennessee Valley Authority (TVA) recently received funds from EPA to use waste heat to stimulate the growth of algae and amur fish in a project designed to recycle nutrients from livestock operations. The project will use livestock wastes to grow algae which will subsequently be fed to amur fish. The amur will then be harvested for livestock food. TVA is also conducting demonstration tests of open-field soil heating, greenhouse heating, and catfish production using waste heat in condenser cooling water.

Numerous other systems have been proposed or are under development for utilizing low-level waste heat in water. Projects that involve stimulation of biological growth have shown the most promise for development. These include aquaculture, mariculture, algae production for animal food, and biological waste-treatment processes. Additional work, however, is needed to identify species of plants and animals which respond most favorably to waste heat stimulation and to adequately control the chemical and biological wastes from these activities. Since they have potential for highly efficient protein production, these processes can also be expected to supplement conventional but energy-intensive agricultural practices.

Efforts are also underway to identify, develop and demonstrate by-product heat recovery situations within industries which discharge the waste in either water or air streams. Some process-specific applications have already been identified and are nearing demonstration through support of EPA's Industrial Energy Conservation Program (discussed elsewhere in this Symposium). For the most part, however, data is still needed on the quantity, quality, and location of waste heat streams so that recovery systems can be evaluated and pursued (when justified).

2. By-Product Electrical Generation by Industry

This option has a good potential for the mid-term (1985 through 2000) reduction of waste heat. A recent study (Ref. 6) implied that an operation of this type could yield a 50 percent savings in fuel, a 50 percent reduction in air emissions, and an 80 percent reduction in waste heat generated (compared to electrical generation in a conventional power plant). Nearly 20 percent of the Nation's primary fuel is used to produce industrial steam, only 30 percent of which is used to generate electrical power before being used for process heating. Most industrial facilities generate their own process steam in a natural gas or oil-fired package boiler and purchase electricity from utilities. Package boilers have been employed rather than field-erected boilers because of their low capital cost, relative simplicity of operation, and the availability of low-cost natural gas and oil. Package boilers usually operate at low steam pressure (below 400 psia) at an operating efficiency of about 75 percent. Field-erected boilers, on the other hand, are more expensive to buy and more complex to operate, but have the capability of operating at higher pressures (with efficiencies up to 88 percent) and last twice as long.

Approximately 43 percent of the industrial steam load is produced in amounts of 400,000 lb/hr or more at single locations. At facilities having this or a larger capability, it would be advantageous to install field-erected boilers and produce by-product electricity in-plant. For example, a coal-fired, field-erected boiler producing steam at 900 psia and 825°F and having a turbine back pressure of 150 psia would have an effective conversion efficiency of 4500 to 5000 Btu/kwh as compared with a heat rate of 9000 to 10,000 Btu/kwh for an efficient central power station (Ref. 6). The electrical power could, therefore, be generated with half the fuel required by a utility plant and electrical transmission losses would be considerably smaller with on-site use of electricity.

Potentially, more than 33,000 MW(e) of additional power could be generated by industrial by-product power units by 1985, resulting in an equivalent savings of 680,000 barrels per day of oil. It is estimated that this could be achieved with a return on investment of 20 percent or more per year before taxes (Ref. 6).

This application has the potential to reduce the environmental impact of thermal and air pollutants, conserve fuel, lower the overall capital needed for electrical generation, and reduce the cost of producing power and process steam. On the debit side, non-utility industries will be required to generate capital for new facilities and will need to upgrade the skills of the boiler plant personnel. However, as the cost of energy continues to rise, it is likely that industries will find that the incentives outweigh the disadvantages. EPA is assessing the technical and economic feasibility of this concept as well as the environmental benefits to be derived from its adoption.

3. Integrated Energy Production/Use Complexes

This option has the potential for waste heat utilization/reduction over the long-term (post-2000). In this application, production and use facilities are designed for operational compatability in terms of energy form, load characteristics, and equipment lifetime. They provide opportunities for increasing the efficiency of energy utilization by 10 or 15 percent. These facilities, however, must be large to interest utilities in a joint venture.

Few integrated energy facilities have been built in the U. S. because of incompatibility of production and user systems, financial risk, lack of necessary capital, and inappropriate long-term planning. Hopefully, the potential economic incentives induced by rising fuel costs will encourage industry, utilities, and government to solve some of the problems which now limit development. The following illustrates what might be achieved.

An integrated coal-fired central station designed to supply 660 MW(e) and 2,000,000 lb/hr of steam at 150 psia (with a 35 percent load factor) could yield an equivalent savings in fuel of 2000 barrels of oil per day (Ref. 6). Air emissions would be reduced proportionally, and considerably less heat would be wasted. EPA is initiating a study to: (1) estimate projected costs of fuel, materials, labor, etc.; (2) formulate 4 promising integrated energy complexes; and (3) assess the economic, environmental, and energy conservation aspects of such facilities at the projected cost levels.

PROGRAM PROJECTION

EPA has been most active in the area of power plant waste heat utilization, having participated (since 1968) in demonstrations of agricultural applications of such technology. Although these efforts will be supported through completion, current and future emphasis is placed more on non-power, energy-intensive industries where waste heat use or more efficient conversion technologies offer significant environmental benefits. Because of the relatively recent attention given to this area and the diverse situations presented across a broad spectrum of industries, assessments will have to be conducted, in many cases, before priority research projects can be identified. In this regard, valuable inputs are expected from an on-going EPA project to evaluate the environmental implications of industrial energy conservation efforts. In addition, a strong interface will be maintained with research efforts conducted by other agencies.

EPA resources will be used to support or supplement research aimed at demonstrating technology which will best accomplish EPA's environmental objectives.

RESOURCE ALLOCATION

Funding for identifiable waste heat projects began in 1968 and has continued on a limited basis. The resources cited below do not include expenditures for in-house personnel to assess potential waste heat applications, nor do they include heat reuse projects funded by EPA's Industrial Energy Conservation Program. Resource allocations since 1968 and projected through FY76 are as follows ($ x 10^3):

Pre-FY76		FY76	
Base	Interagency*	Base	Interagency*
680	300	400	110

*Pass-through funds to TVA for projects identified earlier. FY76 amount is tentative.

CONCLUSION

EPA is involved in assessment, development and demonstration of waste heat utilization/reduction applications which will reduce pollutant discharges and provide other environmental benefits. Some approaches are well developed and near commercial application; others are in the infancy stage and need rigorous efforts to realize their ultimate potential. The impact of waste heat use and reduction on pollutant generation and energy supply is difficult to quantify based on current methodology--as with many projects, the ultimate impact depends on the degree of successful technology development. However, the potential for significant waste heat utilization cannot be denied because the waste heat already is available in tremendous quantities. As noted previously, unless we take the initiative to (1) better utilize waste heat and (2) improve the efficiency of energy production and utilization, the amount of waste heat discharged to the environment by the year 2000 will equal the total U. S. energy demand in 1970. Waste heat utilization, by-product electrical generation, and integrated energy production/use complexes will help to reduce the near-term, mid-term, and long-term discharge of waste heat, respectively. However, because of the state of development, the complexity of the applications, and the long lead times required, it is necessary for industry, utilities, and government to take action on all 3 options at this time. The results should yield significant environmental, economic, and fuel conservation benefits.

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ENERGY CONSERVATION

B. J. Bond, H. B. Flora, B. G. McKinney
Tennessee Valley Authority

Characterization of effluent discharges from power plants is essential for an understanding of the overall impact of a steam-electric power plant on the environment. Further, this characterization is needed in order to more adequately define methods to reduce power plant discharges, thus minimizing the potential environmental impact on the air and water environment and reducing excessively expensive modifications.

The combustion process produces a wide variety of emissions and effluents ranging from various gases and particulates in the flue gas to solid and liquid wastes. Since coal contains inorganic matter in the form of mineral inclusions in the coal and this matter becomes part of the emissions and effluents from a power generating station, the distribution of this matter among the effluent streams of a power generating station is needed. The distribution of some minor and major trace elements is of special interest since some of these elements may be hazardous. These elements are distributed among the ash and gas streams as a function of coal chemical composition, boiler configuration, and the flue gas particulate control device.

As an integral part of the characterization of effluents, existing data from outside and within TVA on the chemical and physical properties of coal, ash, and ash effluents will be summarized and evaluated. Since there will probably be a lack of complete data, one task will be to perform chemical and physical analyses on coal, coal ashes, and ash effluents from TVA plants having relatively different coal sources and different boiler configurations. Also, a literature survey will be conducted to collect and assess the elemental mass balances that have been conducted at steam-electric power plants. This assessment will include an examination of the distribution of elements in the system as a function of boiler design and operation coal type, and geographical location. Deficiencies and problems, if any, will be identified and taken into account in the planning of the overall experimental program; the development of an elemental balance around several different boilers, e.g., wall-fired and tangential; and using coals from different geographical locations. This will allow determination of the differences in ash and effluent characteristics as a function of one boiler design, operating conditions, and coal from a specific geographical location.

The scope of the program will include (1) characterization and quantification of chemical species in coal pile drainage, (2) assessment and quantification of the chemical and physical composition of ash pond effluent after adjustment of pH to meet effluent standards, (3) evaluation of an ash pond monitoring program to determine the sampling program necessary to obtain representative information, (4) evaluation and quantification of chlorinated effluent from a once-through cooling system, (5) assessment, characterization, and quantification of coal ash leachate on groundwater quality, and (6) characterization and quantification of gaseous, vaporous, and particulate emissions from different types of boilers.

All steam-electric power plants that use coal as a fuel source maintain an outdoor coal reserve to ensure uninterrupted electrical generation. Factors which preclude a larger coal stockpile include the cost of land required for storage, workmen, and equipment needed to maintain the coal storage area; the cost of the larger inventory;and environmental effects of coal in storage subjected to precipitation. While the physical volume of coal storage required varies with the plant consumption rate, coal piles are typically 25 to 40 feet high and spread over an area 25 to 100 acres.

Numerous chemical reactions occur within the coal pile. Thus, as precipitation occurs, water seeps through the coal pile, picks up oxidation products, and carries them from the coal pile to a discharge area. Coal pile runoff is commonly acidic and contains high concentrations of dissolved solids. The degree of solids dissolution is attributed to low pH conditions which favor solution of a number of compounds and trace metals. This project will quantify and characterize this runoff as a function of rainfall and flow from the coal pile. Special interest will be devoted to trace elements (approximately 20). Data obtained from laboratory elution testing will be correlated with that collected from the characterization of coal pile drainage field samples.

The steam-electric power industry has effluent guidelines for pH and suspended solids on bottom ash and fly ash transport water. In order to meet the 1983 effluent guidelines, existing power plants will have to either (1) separate the wastewater treatment systems for bottom ash and fly ash transport water and recycle or provide a higher degree of treatment for removal of suspended solids from bottom ash transport, or (2) achieve increased removal of suspended solids from the combined ash transport water. Since it is known that these effluent streams contain dissolved trace elements, it is important to determine how adjustment in pH and suspended solids concentration affect trace metal concentrations in ash pond discharges. It is also important to determine how the chemical characteristics of suspended solids are changed during the process of ash sluicing and ponding. The question as to whether effluents from ash ponds should be limited to "net" or "gross" suspended solids concentrations has not yet been answered. Many of the colloidal clay and other particles which are in the raw water will not settle in coal ponds; and it is possible that trace metals will adsorb on these particles and, therefore, result in higher concentrations of trace metals in the pond effluent. The same number of trace elements as discussed earlier will be examined in this project.

In connection with the effluent guidelines, draft NPDES permits would require TVA to monitor the following parameters in ash and effluent with the corresponding frequency: flow (1/day), oil and grease (1/month), total suspended solids (1/month), heavy metals (1/quarter), and pH (1/week). The above ash pond monitoring frequencies have developed without the benefit of formal study to establish adequate, statistically-sound monitoring frequencies. The proposed frequencies could result in either unobserved, excessively variant parameter levels or too frequent, costly, unnecessary sampling and laboratory analyses. This investigation will involve analysis of available TVA effluent data with the plotting of weekly data on a time basis to display cyclical variations. The degree of correlation between weekly variables will be obtained and studied to determine chemical parameter cross-correlation. In addition to analyzing available data, water sampling programs will be performed on two ash pond discharges to determine sampling frequencies necessary to yield an adequate degree of confidence in representing discharge characteristics.

Since fly ash and bottom ash are normally sluiced to a settling pond for permanent disposal, there havebeen some questions regarding the movement of leachate out of the disposal site into the surrounding soil and groundwater. This leachate may contain trace quantities of potentially undesirable inorganic constituents; therefore, field studies will be conducted at two plants to determine if the migration of leachates through a particular subsoil at these locations is a problem. Also, anion and cation exchange properties of these soild types will be studied to determine their effect on leachate movement. A correlation of the data from the field studies and the laboratory work should elucidate the soils affect on leachate quality.

Another primary effluent stream is the gaseous emission. Studies have succeeded in demonstrating some aspects of the flow of trace elements in the flue gas and the distribution of these elements in various ash fractions. However, studies of the vapor phase trace elements are seldom found and little is known about the trace inorganic composition of fine particulates as a function of particle size. Thus, in view of the potential hazards of toxic elements that may be released from fossil fuel combustion and the need to improve vapor and fine particulate control technology, TVA will quantify and chemically characterize the gas, vapor phase, and fine particulate emissions from two plants with different boiler configurations. Information obtained from this project will enable us to gain a better understanding of gaseous, vaporous, and fine particulate emissions from a power plant and provide a basis for the improvement of control technology for fine particulates and vaporous trace elements. The data gathered will be utilized to evaluate the fractional collection efficiency of the control device, the relative distribution of trace elements in various size fractions of fly ash, and the chemical states in which trace elements exist in these particles and to relate the fly ash characteristics to the type of boiler, boiler operation, coal chemical content, and pulverizer coal size.

The largest effluent stream from most fossil fired power plants is the once-through cooling water. This effluent in most cases is treated with chlorine to reduce slime growth on the condensers. Final guidelines for the discharge of chlorine have been promulgated: free chlorine residual shall not exceed an average 2-hour concentration of 0.2 mg of Cl_2 per liter and a maximum 2-hour concentration of 0.5 mg of Cl_2 per liter. Draft NPDES permits relate this standard to an individual unit's discharge and also state that a study shall be instituted to evaluate all practical methods to reduce total chlorine (free and combined) levels. Before appropriate mechanisms can be proposed to reduce or eliminate the discharge of total chlorine residuals, a comprehensive assessment program will be instigated to determine the quantities of total chlorine residual discharged, its components (free and combined chlorine residual), and chlorinated organics. A characterization of chlorine discharges from a once-through condenser cooling system will be made. Also, an evaluation of the unit efficiency as a function of chlorine usage will be made in order to elucidate the efficacy of different chlorination practices. Recent publications relating levels of chlorine residuals and their toxicity to aquatic life indicate that even lower levels of chlorine discharge is needed. It may not be possible to meet promulgated standards and maintain the current level of electrical generation. Even lower levels could hinder the production of electrical power, thus mechanisms to reduce chlorine residual need to be established.

Even though the zero pollutant discharge concept is now conceived as a goal. Future problems, such as shortages of water and water usage charges, e.g., the western U.S. utilities already face this, will encourage the electric utility industry to investigate alternative mechanisms to reduce environmental impact and conserve our natural resources. As a part of this effort, TVA will investigate the use of membrane processes to render water effluent discharges from electric power plants suitable for reuse in the plant. The basic advantage of the membrane process is that it allows the separation of a dissolved species from a solvent without a phase change and with only a moderate energy input as compared to other processes that produce a similar quality product. This effort is designed to test both commercial and development stage reverse osmosis (RO) and ultrafiltration (UF) membranes for their ability to render power plant waste streams suitable for recycle within the power plant facilities.

A specially designed test unit has been fabricated and delivered to TVA. This test unit incorporates as much flexibility as possible to allow evaluation of all reverse osmosis membranes currently commercially available to industry. Also, some commercial ultrafiltration modules will be tested on the test unit; however, two ultrafiltration configurations--Dual 3-inch UcarSep Ultrafiltration Unit and HFXS Ultrafiltration System--warranted separate test units because of size and flow limitations.

These two units have been purchased and delivered to TVA. Equipment checkout is continuing and experiments will begin in late February on actual field samples from waste streams. This research effort may help define the role that membrane technology will have in the electric utility industry in the future conservation of our natural resources and the development of a balanced environment.

Another part of the effort to reduce the environmental impact of power plants is to investigate one or more mechanisms to reduce entrapment. This effort will consist of continuing the TVA demonstration study to evaluate the efficacy of a fish pump. Also, a review and update of the current published research literature and unpublished literature will be completed and will aid in the development of a document consolidating most of the significant literature on intake structures. Another phase of the study will be field studies to more acutely define the impingement problems associated with intake structures. This will consist of determining the precise nature of factors that contribute to fish impingement at several TVA power plants and then evaluate various mechanisms to reduce impingement and then implement a program to test a mechanism to reduce impingement.

Since the large quantities of water drawn for cooling by steam-electric plants (fossil and nuclear) can cause a potential adverse environmental impact, more efficient methods for the dissipation of heat from power plant discharge waters need to be studied, thus leading to closed cycle cooling and a reduction in water consumption. One possible solution is the wet/dry cooling tower. The wet/dry tower may be operated for water conservation, plume abatement, or outlet water temperature regulation; thus, as a cooling system, it offers a reasonable compromise between the wet and dry cooling systems. TVA plans to purchase a wet/dry cooling tower facility and test it in order to provide the necessary base for evaluating the cooling tower characteristics including wet/dry heat transfer mechanisms, plume abatement, water conservation, and associated energy requirements. TVA is presently negotiating for the purchase of such a facility already constructed and operable. Since the facility does not operate in a closed cycle water mode, a feasibility study is currently being completed to determine if the cost and schedule for closing the water loop is within the budget and schedule of the project. The closed water loop would allow better control of the system, the water chemistry in the system, and its associated impact on performance. Other alternative methods of heat dissipation need refinements and testing. Toward this purpose, TVA will participate in the Cherne rotor spray system full-scale test program since the long-term reliability of a large spray cooling system needs to be fully assessed.

In an area related to heat dissipation, investigations by TVA, directly and/or jointly with other agencies, have been directed to the development of technologies for using low-grade energy contained in power plant discharge water for agriculture or aquaculture production. Development of this energy source will provide the opportunity for fostering economic development and reducing environmental control costs, not only in the Tennessee Valley region, but also throughout the Nation and world. Modern power plants now dissipate from 1.5 to 2.0 units of energy for every unit of useable electrical output produced, or an amount of energy slightly less than 20 percent of all the energy used in the Nation annually. Research and development activities being conducted by TVA are emphasizing food and fiber production. These include: (1) fish farming, (2) environmental control for greenhouses, (3) soil warming to extend crop growing seasons, (4) biologically recycling nutrients from livestock wastes, and (5) environmental control for livestock housing. The need for and relative importance of these efforts have increased recently with the increase in cost of energy for food production and the international recognition of the importance of stability of world food supplies. ERDA through Oak Ridge National Laboratory is cooperating in the development of the greenhouse technology. More recently, EPA has joined with TVA in providing resources to speed up the development of the soil warming and biological recycling activities. Results of this work have been very encouraging. In the soil warming experiments, sweet corn yields were about 50 percent higher on heated plots than on unheated plots. For winter operation, a plastic covered greenhouse (6.7 x 30 meters in size) has been constructed over the warm soil which is heated with buried pipes carrying water from residential water heaters. Future experiments will test yield responses in the greenhouse with tomatoes, sweet peppers, and cucumbers. No heat except from the soil will be supplied to the greenhouse air. Cool-season crops, including cabbage, broccoli, cauliflower, and collards, will be tested on heated soil outside the greenhouse. Small lagoons have been constructed to test a biological recycling system to utilize waste heat and the nutrients in livestock (swine) waste in producing and biologically harvesting (with fish, for example) microbial organisms and/or aquatic plants. A major problem to be studied in future development of the system is maintenance of nutrient quality control of the primary livestock waste.

INDUSTRIAL ENERGY CONSERVATION
AND ITS POTENTIAL ENVIRONMENTAL IMPACT

Herbert S. Skovronek
U.S. Environmental Protection Agency
Industrial Environmental Research Laboratory-Cin
Edison, New Jersey

Various studies have all agreed that industry consumes approximately 40% of the Nation's energy supplies annually, equivalent to some 23 Quads (10^{15} BTU), for comfort control, process heating and cooling, electrical needs, other miscellaneous internal uses and as feedstocks.

TABLE 1. INDUSTRIAL ENERGY USE PATTERNS(1)

(1968)

Direct Combustion	29.0%
Process Steam	44.7%
Direct Electric Heating	1.3%
Motors, Lights, Electrolysis	25.9%

The fraction used for each purpose varies greatly from industry to industry and, undoubtedly, from plant to plant within any one industry. Similarly, the efficiency of use within industries also varies drastically, suggesting that significant opportunity for conservation exists -- on several different levels of sophistication. Based on a variety of predictions that have been made over the past year or two, approximately a 5 - 10% reduction probably could be achieved in the immediate future by such relatively mundane means as improved housekeeping (thermostat control, elimination of heat losses, repair of steam leaks, etc.), improved insulation and improved heat transfer for process equipment. And, in general, more careful control of energy needs in all areas, ranging from boiler through process equipment, could avoid wasteful spikes and valleys in energy use.

Further improvements beyond that stage will require a more thorough examination and reevaluation by each industry of its practices and processes. Such subsequent changes will occur more slowly and, it can be expected, will be more capital intensive and more dependent on evolving technology. Nevertheless, considering the range of efficiencies in energy utilization, it is not hard to conceive of a further 10 - 20% reduction over the next 5 - 10 years. The precise level achieved by each industry will be determined by the availability of different fuel forms, their relative and real cost, the ability to trade-off increased cost for continued productivity, and the price elasticity of the particular industry. In this phase more sophisticated changes such as the recovery of heat in the form of off-gases, hot water, or steam now wasted can be expected to occur through the use of heat exchangers, recuperators, and the recycle or "cascade" use of heat within a plant. In other cases, energy value now being lost through inefficient use of raw materials, incomplete recovery or unnecessary disposal of by-products and unreacted starting materials will be identified and recovered. As usual, cost effectiveness and rapid payback will play a telling role in the rapidity with which such approaches are implemented -- even with existing hardware.

A final alternative exists for cutting energy use even further. Here we must consider relatively complete changes from current manufacturing practices or processes which will come about because of drastic shortages or feared shortages of a specific fuel form, severely increased prices of petroleum products needed for energy generation or as feedstock, or, simply by the introduction of new, more energy efficient technology as our industries apply their technical skills to existing in a competitive, profit-oriented society. Because of the major changes and concomitant risks inherent in such an approach, the frequency may be less but success will often be more productive in terms of the percent of energy or economic saving achieved.

Although the latter two classes of innovation, waste heat reuse and new practices and processes, offer significant potential for industrial energy conservation, they introduce another question requiring simultaneous attention: that of pollution. Drastic changes in industrial manufacturing practices to conserve energy can be expected -- at least in some cases -- to bring about changes in air, water, or solid waste discharges. For example, if an industry or a single plant changes from natural gas to coal, the pollution generated will be much greater and much more harmful, both at the plant site and, incrementally, at the source of the fuel form - the mine (Table 2). Many similar situations can be expected as side-effects of industrial efforts to maintain productivity. Although the nature of the pollution which will result from such changes can, in some cases, be estimated at this time, the environmental impacts of all new, energy conserving approaches should be given special consideration early in their development. Those changes in technology where energy conservation schemes may benefit the environment (waste heat reuse schemes reduce thermal discharges; steam generation from solid waste reduces waste volume; control systems on fuel-firing systems can minimize NO_x generation) should be supported and accelerated, if necessary through Federal assistance programs and regulations. Those energy conserving changes in industrial practices and manufacturing processes where the uniqueness of the pollution or the degree of difficulty of achieving practical, economical control presents major roadblocks to implementation should require parallel development of adequate control technology at acceptable cost before implementation. Similarly, those developing processes where the discharges or emissions are detrimental or are not sufficiently well identified or characterized to allow sound decisions to be made should be subject to additional research so that acceptable and safe pollutant discharge levels and appropriate control technology are available when and if the process technology reaches commercial application. Only in this manner can the economic impact of acceptable environmental control be factored in to give a true evaluation of a new technology. Naturally, in certain other cases, even where completely new processes replace current schemes, there may be little impact on the nature or quantity of pollutants generated or the treatment needed. These processes will succeed or fail on purely economic reasons.

In any case, the environmental impact or the environmental consequences of any altered technology should play an important role, both for the government and for industry, in assessing the desirability and acceptability of new energy conserving technology. It would be both socially and economically unwise for energy conserving technology to be developed and implemented only to face severe and/or costly environmental restrictions or to consume the very energy saved by the process change in add-on pollution control.

When evaluating the subject at the time of the Arab embargo (1973), while awareness of the impending energy shortages was at its highest, EPA decided that a companion environmental program was necessary for the energy conservation programs of industry and our sister agencies, similar to those being undertaken in other energy related areas (power plants, new energy sources, coal conservation, etc.). The environmental program, as it relates to industrial energy conservation, has several facets, consisting of initial definition and assessment of the magnitude of the problems, evaluation of the level of available technology and, if necessary, development of new or improved methods and technology to satisfy specific needs. Responsibilities for identifying and meeting the various objectives of the program were distributed as appropriate to the various EPA research laboratories to assure that both health effects and technology would be adequately addressed.

Of necessity, the program is quite broad, including such aspects as (1) the effect on ambient air quality of improving the insulation and/or sealing of industrial buildings and the effect of increased air recirculation within such a plant; (2) the effect on air, water, and solid waste discharges from plants where increased waste heat utilization might be practiced; (3) the environmental and socioeconomic effects of increased scrap utilization in such industries as steel, aluminum, paper, glass, etc.; and (4) the effect of totally new, energy conserving manufacturing processes in ANY industry, including answering the question of whether adequate and economical pollution control technology currently exists. To assure maximum output with our very limited funds, close liaison has been maintained with other interested and active Federal agencies such as the FEA, ERDA, Department of Commerce and Department of the Interior to assure the maximum possible consistency of programs and minimum duplication. In addition, it was recognized that areas might surface where trade-offs in productivity, energy conservation, and environmental impact might have to be made through regulation for the maximum national benefit. It is the responsibility of those working within this program to identify areas where such policy decisions might be necessary.

As part of EPA's industrial energy conservation program, three primary thrusts have been initiated. The program funding for these areas is shown below:

TABLE 3. INDUSTRIAL CONSERVATION PROGRAM

	FUNDING ($K)		
	1975	1976	1977
Assessment	850	400	160*
Development	435	600	1440*
Waste Heat	50	400	1000*

*1975 Estimates

These are supplemented by other EPA efforts in waste utilization, utility and industrial power plant optimization, coal conversion technology, and advanced energy systems as well as the entire industrial pollution control program. Recognizing that industry will, over the coming years, put into use new process technology which will be less energy intensive, EPA is attempting to assess the environmental impact of such major changes early in their development in order to establish whether the changes offer environmental benefits, present no new problems or create new pollution problems which should and must be considered parallel with the development of the new technologies. In this manner it is anticipated that in-process pollution control can be incorporated in the development sequence and, particularly, in the assessment of the true economic and energy cost of each new process.

At this time, EPA's entire assessment of such new processes is incorporated in one contract being carried out by Arthur D. Little.(2) Based on input from other agencies and industry as well as EPA, ADL has selected thirteen energy-intensive industry segments (Table 4) where new process technology is expected to play a significant role in energy conservation over the next 15 years. Within each industry segment the contractor has selected several changes having high probability of being implemented and has carried out as complete an environmental assessment as possible based on available or obtainable information. The intent of this study is to compare the major environmental impacts of new processes relative to current technology in terms of pollutant types, loads, and amenability to known, economically achievable treatment technology. Where technology (process or pollution control) does not appear capable of satisfying existing or anticipated environmental control requirements, ADL will try to establish what control measures might be appropriate and what their economic and energy impact would be. In some cases, it also may be necessary for the contractor to point out that existing or expected environmental regulations could (or should) inhibit the commercialization of particular manufacturing processes. Where new processes could yield new pollutants, particularly if known or suspected toxicity or health hazard problems exist, the contractor will attempt to identify and flag such problems so that EPA, working together with other Federal agencies, can at least evaluate the risks versus the benefits to be gained.

Table 5 shows some of the processes which have been identified by ADL as likely to be considered by industry for development, or already far enough along in their development that implementation by a significant segment of an industry during the next 15 years is highly likely. It is processes such as these to which ADL will devote its attentions in assessing the environmental impacts and judging whether suitable control technology is, or will be, available as the processes achieve commercialization. Processes now in the laboratory will not be given as much attention since it is unlikely that these will achieve widespread commercialization within the next 15 years.

In addition to the complete studies of the most promising changes, ADL will also present, in more general terms, scenarios for other aspects of the program, such as the potential impact of scrap and the commercial and socioeconomic impact of peripheral areas resulting from process changes such as by-products generated, utility versus on-site power generation, industry siting changes and the effect of transportation.

Beyond the scope of the ADL study, EPA recognizes that a wide range of technology is currently in advanced stages of development. In some cases, these energy conserving technologies also offer environmental benefits; others present real or suspected environmental problems or, at least, major environmental questions. Of course, certain other energy conserving technologies present no significantly different environmental problems; these will not be included in EPA's program but will be developed by EPA for their energy benefits. EPA has initiated a development and demonstration program, albeit a small one, to examine in-process and add-on process and pollution control technology in order to answer environmental questions such as technical feasibility, appropriateness, effectiveness and cost of pollution control. Since various approaches to waste heat utilization offer some of the most promising approaches to energy conservation in the immediate future, this subject will be given particular attention in order to document information that can be broadly implemented in various industrial areas. The current development and demonstration program consists of the following projects:

1. Purification and reuse of heated process wastewater and chemicals in the textile industry.(4)

2. Combined preheating of feed materials and "in process" stack gas pollution control in the glass container industry.(5)

3. Identification and evaluation of potential heat recovery systems in the non-ferrous smelting industry.(6)

Some examples of other approaches to energy conservation coupled with simplified, reduced or eliminated pollution control which could be considered for study if funds became available include:

a. Secondary applications from waste heat streams (on-site power plant, process air streams, etc.).

b. Resale of process wastes and by-products as feedstocks to other industries -- on a national or regional basis.

c. Use of the heat pump to "upgrade" low level waste heat -- such as that generated widely in the food industry. Reuse of that heat, for example, for grain drying.

d. Solventless coating/painting of fabricated metal; solventless printing.

e. Metal recovery from treatment sludges; treatment processes that by-pass sludge generation entirely.

These examples are presented only to indicate the scope of the program, which must, in the long run, provide industry with information to evaluate and select those energy conserving approaches which cause the minimum environmental insult and permit rapid and cost-effective implementation. In addition, it is hoped that careful and sound selection of projects will develop basic concepts and methods which will lead to the invention and application of environmentally acceptable, energy conserving technology over the coming years.

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3. MacLean, R. D., "Energy Use and Conservation in the U. S. Portland Cement Industry." Testimony at U. S. Senate Comm. on Commerce, Public Hearings on Energy Waste in Industrial and Commercial Activities.
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5. EPA RFP No. DU-75-A291, to be funded and initiated shortly.
6. EPA Contract 68-02-1319, Radian Corp., in progress.

Table 2. - Selected Industrial Energy Sources (2)

(1971)

	Steel	Paper	Cement(3)	Glass
Coal	64.5%	13.1	32.0	0.0
Fuel Oils	8.4	30.4	12.0	5.6
Natural Gas	20.6	23.8	37.0	77.2
Purchased Electricity	4.2	11.6	-	17.1
Other	2.6	33.1[a]	19.0	0.0

[a] Residues used as in-plant energy sources

Table 4. - Industrial Energy Use Rankings - 1971(2)

Industry (SIC)	ENERGY USE			
	% of Total Industrial[a]	10^{15} BTU / YEAR	10^6 BTU / TON	10^6 BTU / $ VALUE ADDED
•Blast Furnaces & Steel Mills (3312)	7.3	1.68	19.0	0.16
•Petroleum Refining (2911)	7.3	1.68	0.4	0.36
•Paper & Allied Products (26)	6.8	1.59		
Food & Kindred Products (20)	5.5	1.27		
•Olefins (2869)	4.2	0.98[b]		
•Ammonia (287)	2.7	0.63[b]		
•Aluminum, Primary (3334)	2.6	0.59	173.0	0.72
•Textile Mill Products (22)	2.3	0.54		
•Cement, Hydraulic (324)	2.2	0.52	6-8	0.45
•Glass (-)[c]	1.3	0.31	18.2[d]	0.12[d]
•Alkali & Chlorine (1812)	1.0	0.24		0.52
Motor Vehicle Parts (3714)	0.8	0.19		
Electro metallurgical Processes (3313)	0.6	0.14		
Gray Iron Foundries (3321)	0.6	0.13		
•Phosphorus & Phosphoric Acid (2819)	0.4	0.10[b]		
Lime (3274)	0.4	0.10		
•Primary Copper (3331)	0.3	0.08		
•Fertilizers (2871)	0.3	0.08		

[a] Based on a 23.1 QUAD industrial usage, includes losses in conversion of fossil fuel to electric power.
[b] ADL estimates.
[c] 3211, 3221, 3229, 3296.
[d] Glass Container Segment, SIC 3221 only.
• Included in ADL study.

Table 5. - Some Anticipated Process Changes

Industry	Process	Potential Impact	
		Energy	Environment
Steel	Coke dry quench	~10^{14} recoverable as hi-pressure steam; reduced coke use (2-3%)	Reduced quench water discharge; reduced coke dust
	BOF off-gas collection	~10^{13} BTU recoverable	Reduced thermal, particulate discharges; reduced fossil fuel use
Glass Container	Coal direct fired	Conserve natural gas	Increased SO_2, NO_x, particulates
	Batch preheat	20-35% energy saving	Reduced NO_x, SO_2, particulates
Textile	Solvent dyeing	Up to 50% reduction in steam needs, reduced natural gas for drying	Reduced wastewater; increased solvent emissions
Aluminum	Alcoa Process	~30% reduction in electrical energy	Undefined, closed system possible

DISCUSSION FOR ENERGY CONSERVATION SESSION

Question: This question is quite premature. Are there any regulatory or standard setting activities anticipated in the waste-heat recovery and utilization areas?

Panel Response: No activities are perceived along this line at all. Thermal effluents are the target of regulation and guidelines.

However, there are ways to back into waste heat recovery and utilization. For example, when EPA puts regionally stringent air emissions or thermal regulations on a manufacturing plant, they do, in effect, put double prices on that plant or industry. The result is that other technologies become more competitive, such as recycling some of that hot air and, perhaps, cutting down the volume of the waste discharged.

Question: With reference to the thermal gradients used, are there any studies of potential climatic changes and changes in motion, temperature and light, that arise on a large scale in utilization of this sort?

Panel Response: It's talked about, but there are no actual studies on the subject.

Question: Is the A.D. Little study evaluating, also, the possible alternate sources of mineral raw materials that may be utilized in future industries. The implication of changing raw material sources, for future technologies, seems to be critical.

Panel Response: Yes! Changes in feed stocks are being look at. For example, in the manufacturing industry, the ethane or the gas as a feed stock, with naptha aod oil-gas, are being looked at as an option. In the ammonia industry, coal is being looked at as a basic raw material.

Question: This question concerns itself with the feasibility of implementing waste-heat utilization, through such a device as a hot water utility, for domestic home heating. Certainly, there are hot water utilities in various locations throughout the nation, and there are power plants with hot water to get rid of. Auburn University and Alabama Power Company have begun a plan for the storage of waste-heat from a utility and are actually looking for some distribution. Could someone comment on this possibility?

Panel Response: The TVA is primarily in the rural region. The problems that TVA encounter involves economics associated with heating homes. In considering this aspect, there is a tremendous cost for transport of this low-grade heat to the point that it is used. Transport would be of the range of 20-40 miles.to get it to any city of any size, and the cities are generally small, 40 to 50,000 population. It looks uneconomical to do that, but TVA has not studied it.

In a study termed Municipal Industrial Utility System, heat is taken away from a utility, using it in conjunction with a waste treatment plant, trying to get an entire closed cycle of waste treatment, energy generation and energy reuse. Planning projects are also underway involving industry-utility complex integration. Industries could be relocated to power plant complexes where the power plant would not only supply electricity but would also supply heated water for industrial processes.

There have also been small-scale and desk-top studies on dual water supply system, which relate, of course, to the requirements in some areas for water reuse and the potential for a dual quality supply system; one for drinking water and one for other household and, again, small heated water systems for industrial purposes.

Question; There appears to be a considerable amount of disagreement, or lack of agreement, about the energy costs associated with developing the solar cells, in relation to the energy that's delivered from it, over the effective life of the cells. Could the panel respond to the efficiency of solar cells in terms of the energy budget, and also, what type of projections might be made for energy from solar cells, in terms of the total national energy demands?

Panel Reponse: It's a little premature to be able to answer. Programs have only just begun to get data on the solar systems being developed, and the environmental implications of them. This effort in our laboratory is about five or six months old.

Question: In the studies of waste-heat utilization, is anyone looking at the effects of siting of either the agriculture or the agricultural plot plants, near the power plant site, as it may effect plant growth, or uptake in plants or animals of potentially hazardous materials? Has there been consideration of this in the TVA study?

Panel Response: This aspect is not a specific task, although the plant people are assessing the impact or the liabilities, the productivity and so forth, and detrimental effects of warm water utilization at those sites, and that's probably a difficult item to home in on.

With regard to the TVA Greenhouse Project, TVA will be constructing a half acre greenhouse at the Brownsbury nuclear plant. The heating system is an open path or entry-type system. Water is taken from the power plant condensers which will not contain radioactivity in the discharge. There will be a monitoring program on the greenhouse to determine what are the effects of the hot water on productivity. Projections indicate that plant uptake of contaminants will not be a problem, but there will nevertheless be an intensive monitoring program at the greenhouse.

Question: There are many in the audience here who, over a period of perhaps the last 8 to 10 years, have attended many waste-heat utilization conferences and meetings. Many papers have been heard on the feasibility of the greenhouse (type) projects, catfish farming, shrimp farming, lobster farming, etc. These meetings also included institutional problems. The results of these meetings indicated that the institutional problems associated with trying to get industry to use these systems or projects as a part of their programs is the greatest problem concerning utilization. Is any research going on now, either in Alden's program or the TVA people, to attempt to remove or eliminate some of these constraints that are involved to provide some kind of stimulus for industry to do more in waste-heat utilization? Otherwise it would appear that the program is not really much more than a public relations type of program, because of the small amount of reuse that would be made of the excess heat for any kind of a large station.

Panel Response: The over-riding impetus really is and will be the economics of waste-heat utilization and the energy situation. The current energy crisis, and future energy projections, really makes waste-heat utilization more appealing from an economic viewpoint. Three different types of waste-heat utilization or waste-heat reduction approaches are being looked at. One is basic by-product waste-heat use; that is, waste heat is available - something should be done with it, if possible; secondly, to reduce waste-heat. Here is where the institutional problems become more involved. To reduce its production by making power generation more efficient. Included in that concept is generating power at industrial sites and by-product power generation for steam for process purposes or local power needs. Thirdly, is the integrated supply-use complex which is very futuristic. This concept will probably make more institutional problems. All three are possibilities that we should be considering for increasing efficiency on waste-heat utilization.

With respect to the near-term use of by-product waste-heat utilization, most of the efforts are oriented to the economic aspects. To amplify that point, an EPA-Northern State Power Company jointly supported project was described using power plant hot water for agriculture on a 100 acre site. Three hundred additional acres are available adjacent to the test awaiting the outcome of the demonstration. If the demonstration is successful, there are flower growers knocking on the door waiting in line to lease the 300 acres and expand the installation and operation. Possibly some of the institutional problems are dissolving or are being reconsidered as the interest and the economic feasibility rises.

As stated by other panel members, the economics of waste-heat projects are improved tremendously when, at the time the power plant is designed, waste-heat utilization capabilities and projects are designed into it. If these are added to the plant after construction is completed, the cost of adding them on is prohibitive. So as far as TVA is concerned, they are adding some design characteristics for consideration of waste-heat projects at the time the power plants are being designed.

Question: A number of state public utility commissions are considering the adoption of novel electricity rate structures, such as time-of-day pricing. Is any consideration being given to the effect that these rate structures might have on energy consumption to the utility industry?

Panel Response: None.

Question: Could the panel respond to the effect of putting large amounts of heat and water into the air, as you would get them from wet cooling towers, with the possible exception of the one TVA project.

Panel Response: The one TVA project is the only one with the wet-dry concept that is being evaluated. That is, more from a water conservation standpoint than it is from the matter of heat. However, both are being evaluated at the same time.

The environmental effects of, say, cooling towers and so forth is really not being addressed by this panel. It's more properly the health, ecological effects area. As far as heat rejection from cooling towers is concerned, it has problems in being addressed and evaluated. One of the considerations that must be made is to determine the size a power plant could be without reaching some of these environmental problems.

Panel Comment: Requested an update of the Lanbar Project in Baltimore which was started up last May.

Panel Response: The Landbar Project is, unfortunately, plagued with difficulties, as many start-up situations are. There have been numerous problems. In fact, one kiln has shown up with hot and cold spots causing problems there. The air pollution control device that was installed is not working properly. Those are the two major problems with which the speaker was familiar with.

Comment from the Floor: An energy consultant wished to emphasize that all the work done in energy conservation is not being done by government agencies. The fact of high energy costs of the last few years has stirred an enormous amount of activity in industry to design new plants for heat recovery and in regard to energy crunches. Also, changes are being made to the existing plants themselves to facilitate greater economy of operation.

Panel Response: Government should only serve as a catalyst to the whole program, but industrial response is where the action's at. Industry must do it to stay alive. That is the name of this game, in the United States. Industry will do their job. The government would like to see them do it in the most environmentally sound manner, if possible. There will undoubtedly be occasional disagreement on what is the most environmentally acceptable manner.

Dow Chemical Company has, for the last several years, expanded their energy conservation efforts. In many cases, they are used as a shining example of what can be done by industry in energy conservation by true housekeeping, as well as by process changes and rather innovative plan changes, such as where they end up feeding energy into a municipal system.

Comment from the Floor: Indicated that an analysis is being made for Ontario Fiber Corporation to address the impact to the company associated with changes in utility rate structures. EPRI is also involved in such analyses.

CHAPTER 12

INTEGRATED ASSESSMENT

INTRODUCTION

Following release of the Ray Report, the Office of Management and Budget established an interagency task force on Health and Environmental Effects of Energy Use. An important conclusion of the task force was that the social and economic consequences of alternative energy and environmental policies needed to be considered. The task force report recommended formation of a research program which would integrate the alternatives from two research areas: socio-economic and health-ecological. The integrated assessment program responds to this recommendation.

The problem addressed has become more apparent in recent decades. The development of new technologies and the extension of technologies to new geographic areas has been accompanied by a series of impacts on the economic and social system. Many of these impacts were unforeseen initially, yet they have had far reaching consequences.

Traditional environmental research programs have extended analysis of technologies to examination of first order environmental effects. Such analysis might involve the identification and measurement of pollutant emission from an energy process with the objective of determining the effect on health and environment so that remedial technologies could be devised. The Integrated Assessment Program will carry the analysis one step further by focusing on the secondary and higher order social and economic effects on the community. For instance, the assessment will guage such secondary results as migration of workers, changes from rural to urban societies or other factors modifying the social values of communities, destruction of habitat and changes in land use.

The primary Integrated Assessment research tool is the Technology Assessment. This is defined as the systematic study of the effects on society that may occur when a technology is introduced, extended, or modified with special emphasis on the impacts which are unintended, indirect, and delayed. In addition, the program will employ some supplemental studies and investigations aimed at development of methodologies for conducting the assessments. Modeling will be used extensively with plans to concentrate on the use of existing data and parameters whenever possible.

Four Technology Assessments are either under way or in advanced stages of planning. The four are concerned with: Western Energy Resources, Electric Utility Energy Systems, Development of Large Scale Energy Facilities in the Ohio River Basin, and SEAS, a system of interdependent models of the United States economy. In addition, eight pass-through studies are presently being conducted by USDA, TVA, ERDA, and HUD.

Integrated Assessment of Energy Systems

Edwin B. Royce
Office of Energy, Minerals, and Industry
U.S. Environmental Protection Agency
Washington, D.C. 20460

INTRODUCTION

Several studies are grouped under the heading of integrated assessment, studies having both parallel and unique elements. Individual details will be described in the papers that follow. This paper is devoted to the common basis for and interrelationships between the efforts.

The origin of the integrated assessment program on energy and the environment is found in the Dixie Lee Ray report, The Nation's Energy Future. The program was developed in more detail by the two interagency panels that met roughly a year and a half ago. These panels, dealing with control technology development and environmental effects research, were chaired by Stephen Gage, on the one hand, and Donald King and Warren Muir, on the other.

The report of the Gage panel called for a series of environmental assessments. These were to be studies which would examine various advanced energy technologies, in order to characterize the emissions, effluents, and solid wastes they would produce and to analyze the environmental consequences that might result from their use. The emphasis was to be on translating measurements of emissions and effluents into projections of environmental effects, through the use of existing pollutant transport models and existing data on the health and ecological effects of pollutants.

At the same time, the report of the King-Muir panel called for a program of integrated assessment. Stated simply, the integrated assessments were to translate the results of the environmental assessment activities into forms useful for policy formulation, primarily but not exclusively at the Federal level. The purpose of the integrated assessments was to identify environmentally, socially and economically acceptable energy development alternatives, by the integration of environmental, social and economic research results. The use of the term acceptable rather than optimum energy alternatives was deliberate.

In discussing integrated assessment, the King-Muir panel stressed the importance of carrying out socio-economic studies and analyses paralleling the environmental analysis. There are several reasons for this. First, the costs of pollution control technology must be an integral part of any policy-oriented study. To provide balance, analysis of the benefits of cleaning up the environment should be presented as well. Second, there was broad recognition of the importance of understanding the secondary economic effects of energy technology development and of energy resource development, since such economic development accompanying energy development may itself have major environmental implications. As an example, the development of Western energy resources will result in boom towns and the rapid influx of population. This will cause environmental problems, ranging from rapid increases in municipal wastes, on the one hand, to increased impact on wildlife habitat associated with increases in the number of hunters, on the other.

The program as laid out is intended to include specific treatment of questions of implementation and institutional problems. This is particularly true with regard to energy conservation, and reflects a feeling with regard to energy conservation, that the problems needing research are in the institutional rather than technical areas.

There are two important elements that distinguish the integrated assessment program from the environmental assessment program. First, there is the integrated approach, examining a very broad set of alternatives and consequences that might be associated with technical policy decisions. Second, there is the incorporation of socio-economic effects in the analysis.

METHODOLOGY DEVELOPMENT ACTIVITIES

The integrated assessment program can be divided into two general areas, activities that can be best described as methodology development, and specific assessment studies.

In the methodology area, one of the approaches that can be taken is cost/risk/benefit analysis. The Los Alamos Scientific Laboratory is developing a cost/risk/benefit methodology for doing trade-off analysis between nuclear systems, oil shale, geothermal, and coal use, with specific reference to energy development in the West. This effort is closely related to the regional studies program of the Energy Research and Development Administration (ERDA), particularly the ERDA regional studies program.

The Tennessee Valley Authority (TVA) is developing a variety of methodologies to carry out somewhat different analyses. The ERDA work and much of the EPA work is focused primarily on Federal decision making. The TVA work, by contrast, is focused on regional and local decision making and on decision making within the electric utility industry. What is being developed is a series of tools to expedite environmental analysis, so that adequate electric power can be made available in a cost-effective and timely manner, with minimal impact on the environment. These specific projects are more fully described in the paper by Hickey and Krenkel.

The first TVA project is aimed at improvement in the capability to do the economic projections necessary to drive various models of energy systems and various models for environmental impact analysis. This work is drawing heavily on existing TVA regional economic modeling, modeling which allows the development of long-term projections and deals with such factors as population, employment, labor force, migration, and of course energy. One particular activity under way in this effort is an analysis of the sensitivity of the regional models to National economic parameters. Another is aimed at improvement of impact analysis at the multi-county level, and the development of economic base data for site specific analyses. The studies are specific to the TVA service area. However, an attempt is being made to develop analytical tools in such a fashion that they will be transferable to other areas.

A second TVA project under way is expanding current TVA models to include environmental residuals more specifically. Residuals will include not only wastes in the air and water and solid wastes, but also occupational health problems.

The third project at TVA involves the development and demonstration of computer graphic techniques for both site specific and regional assessments dealing with a mixed system of nuclear, coal, and hydro-electric energy facilities. This work on computer graphics includes the computer display of non-geographical data, as well as the display of geographical data. The intent is to couple to the models an interactive computer graphics capability, such that the combination can be used in system design analyses and decision formulation regarding siting.

The major methodological effort under way in EPA is the continued development of SEAS, the Strategic Environmental Assessment System. This is a model that produces both National and regional forecasts of economic, environmental and energy effects of environmental policies. Part of SEAS is an input-output model of the United States economy, with the capability of disaggregating that economy regionally. The outputs are economic projections in 350 industries, environmental residuals, energy use, and pollution control costs in the 350 industries. The work under way at the present time includes updating the energy demand sectors of the model, and on the supply side, incorporating the Brookhaven ESNS model.

SPECIFIC ASSESSMENT STUDIES

The Department of Housing and Urban Development (HUD) is carrying out a project dealing with the energy, economic, and social impact of energy conservation programs in the residential sector. For characteristic buildings in ten geographical areas of the United States, the economic and the energy savings that would result from various conservation measures are being evaluated. This effort is part of an on-going HUD program in the area of energy conservation in residences.

A major part of the EPA program is an assessment of the consequences of the development of Western energy resources. The approach of this study is the approach of technology assessment, an approach that is also taken in the other major EPA effort under way, an assessment on the electric utilities sector. Technology assessment is essentially a very generalized methodology for systematically studying the effects on society of introducing, extending, or otherwise modifying technology. The paper by Mr. Plotkin has a very good discussion of the application that is being made of this methodology.

The objective of the Western energy resource study is essentially the development of a balanced assessment of the costs and benefits of alternate energy resource development, with the objective of assisting Federal, state, and local decision making in the area. A second objective is to meet EPA's needs with regard to environmental controls and regulation. The study was funded at over a million dollars for three years and is being conducted by the Science and Public Policy Program of the University of Oklahoma, in cooperation with the Radian Corporation. The energy resources being studied in 13 western states are coal, oil shale, oil, gas, geothermal and uranium.

A parallel effort, which is again part of the integrated assessment program, is being carried out by the Economic Research Service (ERS) of the Department of Agriculture (USDA). This effort, described in the paper by Schaub, Barse, and Bender, deals specifically with the economic, social and cultural consequences of coal and oil shale development. Initially the studies are of Western development, but they will be broadened to cover the entire United States. Specific studies that are being carried out include water use and availability, particularly some of the problems of competition for water between energy development and agriculture in the region. These efforts treat not only surface waters, but also groundwater. The ERS is also studying surface mine reclamation, mine reclamation alternatives, and the costs of mine reclamation.

As part of the ERS effort there are a number of studies specific to the Northern Great Plains region dealing with employment, income, population, and financing of government services, all very important impacts of major energy resource development. The effort also includes more general studies of regional economic effects, institutional effects, potential barriers to development, and some questions of perceptions of environmental quality as seen by the residents of energy resource development regions and other parts of the country. The methods that are being developed as part of this study include both local analysis and the development of models to aggregate these local analyses.

The second major integrated assessment under way at EPA deals with the electric utility sector. Again this is a study funded at over a million dollars over three years. The work is being done by Teknekron, Incorporated, of Berkeley, California. The effort will focus particularly on current pollution control policies and strategies. Some of the studies that are included involve energy conversion and pollution control alternatives, and health and ecological effects data and the accuracy of that information. During the first year there will be a focus on coal fired power plants, air pollution associated with them, some of the problems of modeling the transport of that air pollution, and problems of understanding the environmental impact of such facilities.

EPA's Integrated Assessment Program

Steve E. Plotkin
Office of Energy, Minerals and Industry
U.S. Environmental Protection Agency
Washington, D.C. 20460

INTRODUCTION

Following release of the Ray report (reference 1), the Office of Management and Budget established an interagency task force on "Health and Environmental Effects of Energy Use" whose purpose was to:

- examine the ongoing Federal research program in this field;
- recommend an allocation of research funds that would provide an effective research program.

An important conclusion of the task force was that the social and economic consequences of alternative energy and environmental policies needed to be considered along with-and in coordination with-the health and environmental impacts of such policies. The authors of the task force report (reference 2) recommended the formation of a research program to identify "environmentally, socially, and economically acceptable (energy development) alternatives" by integrating results from the two research areas-socio-economic and health/ecological-as well as from research on cost/benefit/risk evaluation and policy implementation alternatives. In response to these recommendations, the Office of Energy, Minerals and Industry (OEMI) established its Integrated Assessment program, which is briefly described in this paper.

PROBLEM STATEMENT

The problem recognized by the Integrated Assessment program is one that has become painfully apparent to society in the past few decades. The development of new technologies-or the extension of technologies to new geographical areas-carries with it a chain of impacts extending throughout the physical, economic, and social systems. Many of these impacts are unforeseen, yet they may have far-reaching consequences that overshadow the direct effects-e.g., the production of energy-that the technologies are designed to create. The traditional research programs of the Environmental Protection Agency have extended analysis of technologies to examination of first order environmental effects. Such analysis includes measuring pollutants discharged from stacks, outflows, etc., computing their ecosystem and health impacts, devising ways of mitigating these impacts, and computing the associated control costs.

The Integrated Assessment Program will carry the analyses farther, by focusing on the secondary and higher order impacts of the technologies themselves and of the environmental controls applied to them. For instance, Assessment research projects will trace the impacts of technologies on land use and migration and measure the associated impacts on: the social structure (e.g., changes from rural to urban society, influx of workers with different social values leading to conflict, etc.); the environment (e.g., influx of population creating sewage problems, destruction of habitats); and on the economy (e.g., labor shortages created by demand for construction and operation workers creating difficulties for prior-established industry and agriculture). The assessments will also trace the effects of environmental controls on the environment, society, and economy.

An obvious corollary to the problem of incorporating social and economic analysis into the health and environmental effects research program is that of insuring that the more focused portions of the Federal energy research program are complete with regard to investigating in detail all of the impact areas of concern. The Integrated Assessment program will be responsible for identifying gaps in the overall research effort that prevent a complete assessment of optimal development and environmental control alternatives. The intended implication here is that work conducted under the program will consist mainly of integrative analysis rather than original research or data collection. When the latter efforts are identified as being necessary to allow a complete analysis, the program will turn to the research programs of EPA and the other Federal agencies for assistance.

APPROACH

The primary tool used by the Integrated Assessment program is the Technology Assessment (TA). Coates (reference 3) defines TA as "the systematic study of the effects on society that may occur when a technology is introduced, extended, or modified, with a special emphasis on the impacts that are unintended, indirect, and delayed." By this definition, the TA precisely fits the analysis requirements defined above. The TA's incorporated in the Assessment program will focus on regional energy development problems and emerging energy technologies.

The appropriate way to conduct a TA remains a matter for argument. TA methodologies range from highly formal structures stressing decision analysis techniques, event trees, and quantitative cost/risk/benefit analyses all the way to relatively unstructured analyses that stress analysis team interaction. In any case, the various techniques for conducting Technology Assessments are described at length in the literature (see references 4 through 7). The Integrated Assessment program is being deliberately neutral with respect to appropriate TA methodologies, at least at this early stage of the program. This attitude may of course change drastically after completion of one or more TA's.

Although selection of an appropriate methodology is obviously critical, successful conclusion of a Technology Assessment may be even more closely linked to the appropriate definition of the scope or boundaries of the Assessment. This definition is linked to:

- identification of the decision-maker(s);
- resources available to the Assessment team; and
- nature of the Assessment subject.

For instance, local decision-makers will usually make decisions based on the impacts on their jurisdictions alone. However, a Technology Assessment addressed to this type of decision-maker must consider what actions outside jurisdictions might take if the client chooses a course of action which is antithetical to their interests. Would a state cut off financial assistance if a locality insisted on pursuing a course of action which hurt its neighbors? A TA that did not consider these aspects would be a failure.

When the decision-maker to be addressed is the Federal government-which is more or less the case here-the definition of project scope becomes quite different. The Federal decision-maker is normally placed in the rather ambiguous position of having to incorporate simultaneously the viewpoints and interests of the Nation as a whole as well as the States and other interest groups. This type of "global" perspective can rarely be fully accommodated in a Technology Assessment, and thus each Assessment will be often reluctantly forced to make critical choices as to the geographical boundaries of impact assessment, the time frames to be examined, the types of impacts to be focused on, parts of fuel cycles to be stressed, etc. In multi-year Assessments, such choices are particularly critical to the success of the first year efforts.

Although the Technology Assessments are the heart of the Integrated Assessment program, a number of other types of project will be undertaken in support of the program objective:

- Supplementary Studies - research projects that will supplement the Technology Assessments, either by providing results that will fill research gaps identified by the Assessments, or by providing increased coverage of issues associated with the Assessments that become identified as crucial to Agency responsibilities. This category will also include integrative studies that fall short of full TA's on topics of concern to the Agency.

- Integrated Assessment Methodology - projects that will develop new methods of conducting Technology Assessments and other integrative analyses. These projects will integrate and adapt the results of research on technology assessment methodology-including cost/benefit/risk analysis, multi-variate decision analysis, etc. - being conducted by the Office of Technology Assessment, the National Science Foundation and other Federal agencies, as well as by the private sector, into a framework which is suitable for Agency decision-making processes. Case studies conducted for these projects will be chosen so as to be supportive of on-going Technology Assessments. This portion of the program will include maintenance and further development of the Strategic Environmental Assessment System (SEAS) model.

- "Pass-Through" Programs - projects supporting the Integrated Assessment program that are conducted by other Federal agencies under EPA funding. Agencies participating in this portion of the program are USDA, TVA, ERDA and HUD.

PROGRAM DISCUSSION

The Integrated Assessment program currently has two TA's fully underway and a third in the active planning phase. These will be described below. Current plans call for the addition of TA's to the program at the rate of about one a year, depending upon the resources available to the program, the scope of the assessment subjects chosen, and the appearance of critical new issues or changes in the urgency of known issues.

In addition to the two on-going TA's the IA program has eight pass-through studies presently being conducted by four Federal agencies. Also, work on the Strategic Environmental Assessment System is presently under contract and in full gear. Other elements of the program - "supplemental studies," and "integrated assessment methodology" (aside from SEAS)- are still in the formulative stage, although a substantial planning effort should have commenced by the time this paper is available.

Those components of the IA program that are either underway or in advanced planning are described below:

1. A Technology Assessment of Western Energy Resource Development

The objectives of the Western Energy TA are:

a. To assist the Environmental Protection Agency in developing environmental control policies and implementation strategies for mitigating the adverse impacts of Western energy resource development.

b. To assist EPA's Office of Research and Development in evaluating that portion of its environmental research program dealing with the problems of Western energy development.

c. To provide a balanced assessment of the full range of costs and benefits stemming from alternative energy resource developments in the Western United States in order to assist Federal and State planning for such development.

The TA is being conducted jointly by the University of Oklahoma Science and Public Policy (S&PP) Program (publications: "Energy Under the Oceans","North Sea Oil and Gas", "Energy Alternatives: A Comparative Analysis") and the Radian Corporation ("A Western Regional Energy Development Study"). The Project Director is Dr. Irvin (Jack) White, professor of political science at Oklahoma University and assistant director of the S&PP Program.

The Assessment will focus on the impacts of developing coal, oil shale, oil, natural gas, geothermal and uranium resources in 13 western states. Development of these resources, and especially of coal and oil shale, has become a source of extreme contention among interest groups both within and outside of the region, largely because the impacts, positive and negative, are separated spatially and temporally. For example, the development will satisfy demand for energy largely outside of the region, in the Midwest and Pacific Northwest, while environmental damages will largely accrue inside the region. Although in the long term the overall financial position of the resource states may improve from the expanded tax base created by development, short term demands for services such as education, housing, and other services associated with a rapidly expanding population will create a severe strain on regional finances.

The Assessment team does not favor a highly structured approach to Technology Assessment, and thus there is a deemphasis of formal decision analysis and cost/risk/benefit tools and model building. Impact analysis will focus on a series of site-specific and regional scenarios. Energy development levels are set by assuming levels of national energy demand based on previous forecasts, and allocating portions of the supply response to the region (possibly by utilizing the Gulf-SRI model). During the first year of the study, the "boundaries" can be specified as follows:

. All portions of the fuel cycle (except end use) are considered except that the uranium fuel cycle is examined only to the milling stage:

. The focus of attention in impact analysis will be the eight major resource states. Impacts outside the region are not considered in depth, with the possible exception being at electricity demand centers in the Midwest: and

. Exogeneous variables affecting development rates are not examined in depth.

The implication of these boundaries is that the Assessment is focusing, in the first year, on the question of how to cope with development if it occurs. The parallel questions that a "complete" Technology Assessment would attempt to answer - whether or not development should occur, and how to promote the level of development desired (or, at least, how to predict the level likely to occur) - require analyses considerably beyond the first-year study boundaries.

The Western Energy TA is supported at a level of $1.3 million over three years, with the potential for additional support from the Supplementary Studies portion of the Integrated Assessment program.

2. A Technology Assessment of Electric Utility Energy Systems

The Electrical Utility TA has the following objectives:

a. To provide a means of testing pollution control policies and strategies with respect to the utility industry which must be formulated in response to current and near term issues.

b. To identify those issues, especially environmental issues, which are likely to require policy decisions in the future and identify the research programs which should be initiated to provide a sound basis for future decisions regarding these issues.

The TA is being conducted by the Energy and Environmental Engineering Division of Teknekron, Inc., Berkeley, California ("Comprehensive Standards: The Power Generation Case", "Economic Impact of Water Pollution Control on the Steam Electric Industry"). The Principal Investigator is Dr. Peter M. Cukor; the Project Director is Mr. Glen R. Kendall.

The Assessment will focus on the energy conversion and pollution control technology alternatives, health and ecological effects, and resultant national economic impacts associated with activities of the electrical utility industry. Rapid depletion of the readily accessible alternative domestic energy resources for electrical power generation, coupled with international concerns about the quantity and security of imported oil and gas, has produced a major tilt in the industry in favor of nuclear fission and coal combustion as the electricity-producing technologies of choice over the next decade. The future development implied by these forces-involving development of new mining areas and increased production in established areas, development of vast new transmission facilities, construction of extremely large fossil and nuclear generating facilities, and a vast quantity of supporting development-may result in the creation of new (and the exacerbation of existing) environmental, social and economic problems that demand the close attention of the Federal government.

In contrast to the Western Energy TA, which is considerably broader in terms of the "actors" who play significant roles in affecting the course of development, the Electric Utility TA is viewed by Teknekron as linked very closely to the actions of one industry as it is affected by external forces. Thus, Teknekron's approach to conducting this TA relies heavily on expanding and improving a model of the behavior of the electric utility industry. A parallel effort will be conducted to critically review and analyze the data and models available to measure the impacts of alternative development, and to analyze the sensitivity of current assumptions and practices of emerging political and social changes. For instance, a particularly important part of Teknekron's work will involve a thorough review of the mechanisms of atmospheric transport and transformation of sulfur oxides and their associated health impacts.

During the first year the TA will be sharply restricted in scope to:

. Focus primarily on existing coal technologies and secondarily on other fossil fuel technologies;

. Focus on the power plant portion of the fuel cycle;

. In terms of environmental impacts, focus on air pollutants and, more specifically, on long distance transport and atmospheric chemistry of fine particulates;

. Generally confine air impact analysis to defining exposure of populations to pollutants without defining health effects or aesthetic or economic damages.

The Electric Utility TA is supported at a level of $1 million over three years, with additional support possible from the Supplementary Studies program.

3. A Technology Assessment of the Development of Large Scale Energy Facilities in the Ohio River Basin

The FY 76 appropriation bill contained a rider requiring the Office of Research and Development to conduct a study of the Lower Ohio River Basin, to "be comprehensive in scope, investigating the impacts from air, water and solid residues on the natural environment and residents on the region" which might result from an increasing concentration of power plants in the Ohio River Basin. The Integrated Assessment program plans to conduct this study as a Technology Assessment. The scope will be broadened to include development of both power plant and coal-based synthetic fuel plants in the Basin in Indiana, Illinois, Kentucky and Ohio. Major focus will be on an in-depth examination of the impacts of energy development on the region, along with analysis of mechanisms to mitigate the adverse impacts and shape development along desirable lines. Additional attention will be paid to extra-regional concerns-for instance, to the role of Basin development in meeting national energy requirements, and to the question of long distance transport of sulfates.

The study is currently in the planning stage. The IA program has engaged the Program of Policy Studies in Science and Technology at George Washington University to aid in the planning necessary to initiate the study; this work is being carried out by Drs. Jerry Delli Priscoli and Vary T. Coates of the PSS&T Program in cooperation with the OEMI staff.

4. Strategic Environmental Assessment System (SEAS)

SEAS is a system of interdependent models designed to forecast the economic, environmental and energy consequences of alternative Federal environmental policies under varying assumptions about the future. The core of SEAS is an input/

output model of the United States economy (INFORUM) which models the interactions between different economic sectors.

SEAS is capable of developing estimates to 1985 of:

a. economic projections in terms of physical output for 350 industries and processes;

b. pollution control costs for 500 control technologies;

c. projections of environmental residuals and energy use for each of 350 industries.

Past SEAS applications include:

a. generation of Cost of Clean Environment reports by EPA;

b. analysis of Effluent Guidelines by National Council on Water Quality;

c. other applications by EPA, BLM, NIH, OTA.

A detailed description of SEAS is available in reference 8.

SEAS represents a potentially important tool for integrated assessment and is thus being maintained and developed further under the Integrated Assessment program. For instance, SEAS offers the potential to measure the national impacts of new energy development to complement the focus on in-region impact of the regional TA's (such as the Western Energy TA). This type of measurement is crucial if Federal decision-makers are to take into account all of the potential impacts of development alternatives.

The present SEAS program includes the following:

a. Data Maintenance - continuously updating SEAS data bases using the results of new studies, surveys and analysis.

b. Applications - using SEAS in support of the Technology Assessments or other Agency requirements.

c. Model Additions and Improvements - improving the capabilities of SEAS to deal more effectively with energy-related issues.

Work currently in progress to improve SEAS includes the development of additional capability to predict energy demand in the transportation, residential and commercial, and industrial sectors. For instance, a new transportation model will forecast activity (VMT, or vehicle miles traveled), emissions and energy demand, with feedbacks to the input/output model to account for changes in automobile mix and transportation efficiency.

Another important part of current work is the integration into SEAS of the Brookhaven National Laboratory's ESNS energy supply model. Addition of ESNS will allow the study of new energy sources including coal gasification and liquefaction, oil shale, off-shore oil drilling, and geothermal and solar energy.

SEAS work for the IA program is currently supported at a level of $150,000 per year, with additional funds potentially available for applications.

5. Pass-Through Program

The IA program has cooperative agreements with four Federal agencies to have them conduct studies designed to meet program objectives. Since these studies are described in detail in the complementary papers of this session, they will merely be listed here and their FY 76 (EPA) funding levels specified.

a. Economic Research Service, U.S. Department of Agriculture - "Estimation of Economic, Social and Cultural Consequences of Coal and Oil Shale Development" $396,000.

b. Tennessee Valley Authority -

(1) "Develop Economic Projection Modeling Capability Necessary to Drive Modular Energy and Environmental System Planning Models at a Multi-county (Economic Area) Level" $54,000.

(2) "Electric Power System Residual Output Model" $53,000.

(3) "Develop and Demonstrate Applications of Computer Graphics to Site-Specific and Regional Integrated Environmental Assessment of Mixed Nuclear, Coal-based, and Hydroelectric Energy Systems" $131,000.

c. Energy Research and Development Administration -

(1) "Develop a Methodology for Cost/Risk/Benefit Tradeoff Analysis of Nuclear, Oil Shale, Geothermal, and Coal Use for Power Production in the Western States" $115,000.

(2) "Coordinate National Design for Environmental R&D Information System" $35,000.

d. Housing and Urban Development - "Determine the Energy, Economic and Social Impacts of Energy Conservation for the Residential Sector: For Characteristic Buildings in 10 Geographical Areas" $92,000.

INTERAGENCY PARTICIPATION

As noted above, a portion of the Integrated Assessment program is being performed by other Federal agencies with funds provided by EPA. In addition, interested agencies of both Federal and State governments, as well as business and environmental groups and other organizations, have been asked to participate in the Technology Assessment activities through the mechanism of Sector Groups (established by OEMI to coordinate, evaluate, and prioritize research in well-defined areas of energy activity). Members of the Sector Group are briefed on TA activities and are asked to evaluate Work Plans and other project outputs. Finally, cooperative arrangements are being worked out, on an ad-hoc basis, for coordination between IA projects and relevant projects being conducted by other Federal agencies. For example, arrangements are being formulated with the Council on Environmental Quality to have a data exchange and analysis of equivalent scenarios between the Western Energy TA and the Council's Phase III Western Regional Energy Development Study.

CONCLUSIONS

Although the Integrated Assessment program is in its infancy, the two Technology Assessments are well enough along to have surfaced several important issues for the program. First of all, the TA's tend to deal with issues that go well beyond the traditional interests of the Environmental Protection Agency. Thus, coordination with interested Federal agencies and other entities is vital not only for information - exchange purposes but also to prevent questions of the "propriety" of the research from hindering its progress. It has also become clear that the objective of incorporating social and economic concerns into the decision-making process is extremely ambitious. Defining useful but realistic analytical boundaries is clearly one of the most crucial - if not the most crucial - problems facing the program. The danger here is that these boundaries may be set so wide that the level of analysis will become too shallow to be credible.

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RESEARCH PROGRAM ON THE ECONOMIC AND SOCIAL CONSEQUENCES OF COAL AND OIL SHALE DEVELOPMENT

John R. Schaub
Joseph R. Barse
Lloyd D. Bender
Economic Research Service, USDA
Washington, D.C.

INTRODUCTION

The U.S. Department of Agriculture is conducting research and informational programs which address many issues concerning expanded coal and oil shale development. These programs are the responsibility of several departmental agencies and concern the reclaiming of mined and orphaned lands, developing and propagating plant species for these lands, conducting soil surveys, and assessing social and economic consequences of coal and oil shale development. To a significant extent, these programs, which are being coordinated within the Department, are made possible by transfer funds from EPA. The Economic Research Service is responsible for dealing with the socio-economic implications of coal and oil shale development. This research contributes to the EPA Integrated Assessment Program.

When EPA was planning its energy research program in 1974, interdepartmental task forces were organized to determine critical informational and analytical needs and to identify expertise that could effectively meet these needs. We are pleased the task force recognized the need for an integrated assessment of various energy development activities. These assessments are critical to individuals and policy makers at all levels of government --local, state, and federal.

The Economic Research Service has a responsibility for developing information on problems and issues affecting supplies of food and fiber and for evaluating the effect of various agricultural and rural policies and programs as they relate to the use of natural resources, agricultural production and productivity, and the social and economic vitality of rural communities. The expertise required to assess the socio-economic impacts of coal and oil shale development closely parallels the expertise developed in the ERS ongoing program. EPA recognized this capability and provided funds for ERS.

SCOPE OF PROJECT

ERS planned and initiated a research program that takes into account many of the socio-economic impacts and implications of coal and oil shale development.

The research proceeds toward 12 objectives. Completion dates for portions of the work range from 1976 to 1981. Initially, work focuses on the impact of coal and oil shale development in the Western States. Later in the project, Interior and Eastern States will be brought into the analysis.

The 12 objectives follow:

1. Develop regional reports on current land and water use and the agricultural economic implications for future resource use, resource competition and environmental quality resulting from alternative levels of coal and oil shale development and related activities. These reports will draw primarily upon existing information for major coal and oil shale areas.

2. Estimate the impact of energy development in the Northern Great Plains on employment, income and population of rural communities. Methods will be developed and tested to estimate and analyze changes in population, income, direct and secondary employment which result from additional mining and related activities. These methods are to be applicable to the assessment of impacts on communities in other regions.

3. Assess the impact of energy development in the Northern Great Plains on local government finances and services, including state severance taxes and other financial instruments, in terms of revenue potential. Analyze the interrelationships of local government expenditures to employment, population, income, age structure and other socio-economic variables.

4. For selected sites, evaluate reclamation costs for alternative technologies and uses of reclaimed land.

5. Develop an analytical system to evaluate interregional economic implications and trade-offs for agricultural and rural areas resulting from coal development.

6. Evaluate the economic effects of various levels and types of energy development, processing, and transportation on the demand for water and the economic life of aquifers. Develop implications for interregional transfers of water, and evaluate site and off-site effects of increased water demand on agricultural industries, environmental quality, and rural resource use.

7. Determine the effect of institutions, including water, mining and reclamation laws, on mining potential, incidence of cost and equity.

8. Develop methodology to integrate secondary economic impacts of energy development on employment, population growth and income (item 2) with governmental finance and services (item 3)

resulting from energy development in the Northern Great Plains and obtain analytical results.

9. Revise and update regional reports using data, information and research results not available at initiation of the project. Included would be recently completed work on reclamation, land classification, soil mapping, and pollution discharges of various activities. Also, to the extent development has taken place, the socio-economic and environmental impacts associated with the development would be taken into account.

10. Restructure the interregional analytical system and revise estimates of regional and interregional economic impacts on resource competition, resource use and environmental quality using output from item 9.

11. Develop information on and construct measures of levels and perceptions of environmental quality, including aesthetic, recreational, visual and other desires related to socio-economic benefits and costs associated with mining, transportation, and processing.

12. Interrelate the interregional analytical system (item 10) with secondary socio-economic and governmental impacts (item 8). The most recent technical information on reclamation and revegetation as well as measures of environmental perception and environmental quality (item 11) will be incorporated.

METHODOLOGY

Much has already been done to assess certain impacts of intensified energy development in the U.S. Some of this assessment is based on alternative scenarios of energy resource development over periods of time ranging to 2000 and beyond.

However, existing assessments or models tend to be either highly aggregative or limited to one or several specific sites. By contrast, our efforts will combine local and aggregative approaches, moving back and forth from assessing local to regional impacts to interregional trade-offs in the analysis. Many different kinds of local and aggregate impacts on land, water, agriculture, employment, incomes, public budget and government services will be joined into one integrated assessment of the effects of energy extraction, transportation and processing. A central concept is that of homogeneous (or approximately homogeneous) producing areas (HPA's) as the smallest geographical units in the analysis. These will be the units for local analysis. These areas are used for organizing, presenting, and working with the body of data through which energy development impacts are to be expressed. Data for these HPA's will be the building blocks for the assessment.

Analytical systems will employ linear, or if appropriate, nonlinear programming to rationalize future or alternative allocation of extractive, reclamation, transportation and energy processing activities among HPA's and regions in accord with appropriate constraints and objective functions. In the future, input-output analysis may be warranted. Impact assessments will be made on only a piecemeal or regional basis during the model building phases of work, but as the model building progresses, both intra and interregional trade-offs will be evaluated.

As now planned the interregional analytical system will evaluate the cost of meeting alternative coal demands (without reallocating present output) subject to several constraints. About 20 demand points will be isolated in the United States for purposes of specifying transportation costs and estimating changes in quantity demanded. Each of the homogeneous coal production areas will contain specified quantities of each coal quality. Qualities are based upon BTU and sulfur content. Constraints on output are (a) capacity, (b) revenues, and (c) water. Capacities limit the rate of exploitation, while revenues and water are constraints on resource availability. The exact form of the capacity constraint is not now defined. Probably the most binding of several possible constraints (such as machinery availability, leasing, timing, or rail capacity) will be imposed.

The model will account for land and labor use, reduction of reserves, and environmental costs. At a later time the cost of externalities could be incorporated explicitly but no plans have been made. Present plans are to incorporate known and anticipated on-site facilities, then allow the model to endogenously site new facilities. In either case, this feature is 3-4 years away.

The basic philosophy of the modeling work is to get a basic model operational, and then incorporate additional features. Along the way, reports are anticipated for each of the 12 objectives.

ORGANIZATION OF PROJECT

Two divisions within the Economic Research Service are involved in the study of the impacts of energy development. While research responsibility is divided between these divisions, there are also common research objectives which require collaboration between divisions. Work of the two divisions on this project matches their on-going research programs. The Economic Development Division is concerned with population, employment, migration, incomes, and the provision of governmental services. The Natural Resource Economics Division emphasizes natural resource use and environmental considerations. Administratively, the overall research management is the responsibility of the Deputy Administrator for Resource and Development Economics. A project manager has been assigned to facilitate research coordination and liaison requirements.

Each division, in turn, has identified a research leader to supervise the work within his division.

The research underway in ERS is being carried out by our staff located in Colorado, Minnesota, Montana, North Dakota and Washington, D.C. In the future, we anticipate the location of research will change to some extent when the eastern and interior regions are brought into the analysis. We expect that our major effort will be in-house, although we have entered into some contracts or cooperative agreements for various portions of the research and expect to enter additional agreements at a later date.

NEED FOR COORDINATION

In developing this project it is necessary for ERS to cooperate and coordinate with others doing related research. The research task is so broad and complex that with the limited funds available duplication of efforts must be avoided. This is especially important with respect to developing the basic data needed for analyses. Additionally, it is important to assure, to the extent possible, that the research is additive and complementary.

Our staff has established contact with various individuals and institutions working on energy-environmental research. EPA has a primary responsibility for coordination and has worked with us on this important activity. However, we realize our efforts can be further coordinated and intensified. This symposium offers an ideal opportunity to move towards better coordination and cooperation. We welcome our involvement in this symposium.

Integrated Assessment

H. R. Hickey and M. C. Babb
Tennessee Valley Authority
Chattanooga, Tennessee

INTRODUCTION

The energy crisis has reemphasized the importance of electric power in maintaining a vigorous economy. But the quality of the environment must be protected, and extensive planning and assessment is necessary before power generating capabilities can be expanded in a responsible manner. To meet these objectives, planning and impact assessment activities have intensified to the point that there is significant, costly delay between the time that need is first identified for a power generating facility and the time the facility actually becomes operational. For the typical nuclear plant this period is about ten years. Much of this time is required for iterative planning and environmental impact analysis. Procedures for expediting these activities and for improving their reliability are essential in assuring adequate electrical power in a cost effective, timely manner with minimal adverse environmental effects.

When new generating capacity is delayed, the only alternative rapidly available is the use of combustion turbines. The cost per delivered kilowatthour for these oil-fired turbines is more than thirty times that of hydroelectric power and seven times the current cost for nuclear power, at current fuel and operating costs.

The Tennessee Valley Authority's EPA-funded Integrated Assessment program shows promise of evolving into a system which will speed the planning and impact assessment of existing and proposed power generating facilities. Integration of these activities consists of (1) improving lines of communications between planning, engineering design, and impact assessment workers; (2) developing a unified data base containing information for use by a variety of planning and impact assessment activities; and (3) using more efficient techniques for data display, analysis, and management decision making.

For possible use in the exchange of information or coordination, the names of principal investigators, research investigators, and responsible administrators are included after the title of each task.

DISCUSSION

TVA's Integrated Assessment research is divided into three specific tasks, which will improve the methodology for projecting energy demand, provide a residuals model to improve total power system planning, and develop computer graphics applications to speed and improve the quality of environmental impact analysis of alternatives.

1. Develop an Economic Projection Modeling Capability Necessary to Drive Energy System Planning and Environmental Impact Assessment Models--H. Hinote

For several years, TVA has been developing an economic model for the TVA region. Systems simulation (based essentially upon the techniques of Jay Forrester in Urban Dynamics and H. R. Hamilton, et al, in Systems Simulation for Regional Analysis) was selected as having the most potential for fulfilling TVA's need for a tool to support the planning of additions to the power generating and distribution system, development of an improved water resources program, and the evaluation of socioeconomic impacts of such activities. The model was designed to provide: (1) long-term projections of such factors as population, employment, labor force, and migration utilizing alternative assumptions about components of the demographic and economic sectors, and (2) impact and sensitivity analysis to give additional information about the questions of "what can be expected if" certain basic assumptions change (e.g., birth rates, growth rate of certain industries, accessibility to markets, etc.). The basic model consists of a demographic sector, divided into 14 racial and age groups, and an employment sector, divided into 6 manufacturing and 5 nonmanufacturing categories with interactions and feedback loops between them. Projections using this model apply to the 80,000-square-mile TVA power service area, but the model is being designed to be used for any homogeneous economic area for which sufficient data can be accumulated. By early 1975, TVA had this model installed on its computer system; however, to make the model an operational tool for use in driving modular energy and environmental models, additional work was required.

The objective of the current work is to expand TVA's existing Regional Economic Simulation Model for use in (1) assessing an area's sensitivity to various national parameters--e.g., national employment growth rates, zero population birth rates, (2) evaluating the impacts on the population, labor force, employment, etc. at a multicounty level of an incremental expansion to the energy generating system, and (3) providing the macroeconomic data base required for site specific analyses. The expanded model would, therefore, provide (1) the basic demographic and economic projections necessary, at both a regional and subregional level, to derive projected energy load forecasts and socioeconomic impacts on the socioeconomic sector; (2) alternative projections, in relatively short periods and low costs, necessary to better evaluate alternative energy sources and expansion strategies; and (3) the framework for improved socioeconomic analysis of specific sites.

During the past six months the following progress has been made:

1. A reexamination of the migration function in the current model was completed by a

consultant from Northern Illinois University. The conclusions were: (1) the equations to estimate the gross flows disaggregated by age, sex, and race are to be preferred for modeling use; (2) however, incorporating these equations in the program would require major restructuring of the model; and (3) at the present time not enough is known about gross migration flows and their determining factors to adequately restructure the model. Based on these conclusions, the current method for projecting net migration is being reexamined to evaluate the feasibility of incorporating additional social and economic parameters affecting that component of the model. Currently, we are investigating ways for improving the net migration estimating equations.

2. The labor force participation function was reestimated based on data for southeastern labor markets and incorporating 1970 census data. The reestimated function has been incorporated into the model.
3. A household estimating routine was incorporated in the model. However, additional research has been found necessary to project the number of persons per household after 1980.
4. A detailed examination of the existing manufacturing employment projection algorithm was initiated. An alternative was formulated and some of the necessary data have been gathered for testing the design concept.
5. Input data for the model were assembled and the computer program was run with the improvements mentioned above for the 170-county TVA power service area. The model was verified for the period 1960-1974 and the output is currently being used by the Office of Power in developing its load forecast for next year.

Research yet to be completed includes expanding the existing model to provide projections of manufacturing employment at the 2-digit Standard Industrial Classification (SIC) level. In addition, extensive testing and verification must be accomplished before the model will become operational.

2. Expansion of the Power System Simulation Model to Include the Prediction of Environmental Residuals--Floyd E. Davis, Ray E. Hoskins

The objective of this research is to develop the methodology for predicting environmental residuals at each power generating facility of TVA's system using the output of TVA's power system simulation model. This model is a part of the overall Power Program Integrated Planning Model which is being developed by TVA's Office of Power in an on-going effort to complement and expedite current planning methods.

The power system simulation model predicts future operational states of the power system over a selected time span. Power system states are characterized by plant capacity factors, maintenance and refueling schedules, reliability indices and pollution abatement techniques. Various types of transformation equations that relate the operational state characteristics to environmental residual generation are being investigated. Residuals include air and water pollutants, solid wastes, occupational health events, and impact-producing inputs (e.g., the materials requirements for a particular type of power generating unit). Residuals prediction will serve as input into impact assessment models and for evaluating operation and expansion policies of the power system. Although this model is rather complex, recent programming modifications have greatly reduced its run time. This development now makes long-range simulations (10 years) practical.

Current research includes compiling a list of residuals together with the units and time scales which are required as input into impact analysis schemes. Data requirements for various transforms are being assembled. Nonlinear residual generation is being quantified for several processes. Development of transforms will be coupled with evaluation of available data.

3. Develop and Demonstrate Applications of Computer Graphics to Site Specific and Regional Integrated Environmental Assessment of Mixed Nuclear, Coal-Based and Hydroelectric Energy Systems--Malcolm C. Babb, H. R. Hickey

The objective of this research is to demonstrate the use of interactive computer graphics as a means of expediting and improving the environmental impact and related cost analysis of existing and proposed power generating facilities. It is important to note that the emphasis will not be restricted to the spatial display of environmental data, that is, the mapping of distributions of environmental variables. While this capability will be a part of the project, we see the greatest benefit in development of interactive analysis capability to relate impacts to control technology alternatives more rapidly and exhaustively, especially for cases where differences of tens of millions of dollars are at stake at a given power plant site. Current research efforts are directed toward three general areas.

First, many mathematical models used for environmental impact assessment produce complex and voluminous output which is analyzed currently by cumbersome and time consuming techniques. Interactive computer graphics methods are being developed to expedite analysis by computer simulation using mathematical models, and to improve the management, display, synthesis and reporting data. Specific applications planned include the development of analysis schemes for managing the output of air and water quality models as well as radiological dose calculations. In these applications the numerical output of these models is temporarily stored in a computer file. Depending upon the wishes of the investigator, portions of this information can be selectively displayed on a cathode ray tube (CRT) in a variety of scales and formats, or in conjunction with other information that may be useful in the analysis. For example, the data may be listed in tabular form together with a graph of the data. A parameter may be changed, and a new graph produced as report-ready hard copy in a matter of minutes. A more complex display related to air pollution analysis might be a plot of concentration isopleths for a selected pollutant overlayed on a map of topography and population distribution. The investigator can also select from a variety of analysis routines such as statistical programs which compare model-predicted results with actual field data, or display the results of statistical tests. Where possible the predictions made by these models will be related to costs of control technology. For example, these control alternatives may hinge on environmental impact and can involve differences of $30 million for cooling systems alone at a single plant.

This research has already revealed the need to develop analysis schemes which can be carried out by a person with only a limited knowledge of computer programming. Interactive programs are designed to free the investigator from data handling, processing and display technicalities and enable him to concentrate upon information synthesis. This is exactly the same approach already well established in engineering design and architecture called "CAD," or computer-assisted design.

A second area of research concerns the development of a computer-oriented geographical information system. Much of the data used for power plant siting and impact assessment can be referenced to geographical location. Currently there is no unified system for efficiently managing this information so as to make it readily available to all users. The state-of-the-art is under review, with recommendations to be made for an approach TVA should adopt which will be most sensible, in light of other developing systems and TVA needs. The geographical information system will provide a uniform basis for storing and manipulating a variety of engineering, socioeconomic, land-use, demographic, and environmental data that are used for power plant siting and design studies and impact assessment. In fact, this may make possible improved iteration between these planning elements--a laudable goal.

The user of this system will be able to display geographically referenced information at a variety of scales and in formats which are either directly compatible for analysis (maps, overlays, etc.) or which can be transformed to the required format with minimal effort. Included in these data manipulations are a variety of programs which can expedite either horizontal or vertical spatial analysis of the data. The results of a vertical spatial analysis typically are maps displaying multiple variables in a given area. Horizontal spatial analysis routines generate maps showing, for selected variables, relationships between adjacent geographical locations.

The geographical information system will also allow the reduction of data with a variety of formats and from many sources to a common basis compatible for entry into storage files. Computer graphic techniques will expedite data entry, correction, display, and analysis.

Another area being explored for possible application of computer graphics is socioeconomic impact analysis. A state-of-the-art review will survey current techniques for socioeconomic impact assessment of proposed power generating facilities, including TVA's. Data requirements are being identified with a view to merging with a geographical information system. Socioeconomic data display and analysis schemes that will be accelerated by use of computer graphics have been identified.

SUMMARY

Integrated assessment research is planned for five years. The first year's efforts have been concerned with program integration and detailed planning of identified tasks. During the second year, implementation of the geographical information system will begin. Regional siting methods are planned for demonstration, and a multicounty region surrounding a potential power plant site will probably be selected for demonstration purposes. The techniques developed will then be used to demonstrate the value of integrated environmental assessment in power system planning, environmental impact and cost analysis, and management decision-making.

DISCUSSIONS TO INTEGRATED ASSESSMENT

Comment from the Floor: Indicated that a book by Wilson Clark, "Energy for Survival - An Alternative to Extinction," is a book mentioned in the February issue of the Energy Reporter. Senator Michael Bell lso puts out an excellent energy newsletter. Speaker also emphasized the need to do more.

Comment from the Floor by EPA: As mentioned before, this program is in its infancy so there is not a complete program at this time that spans all energy systems in all geographic regions. Solar energy will certainly be one of the energy systems addressed.

Question: Several studies are being done in terms of the impacts on communities. Will any of these studies include land use controls to make sure there aren't additional energy impacts because of bad land use and does it also include the development of new institutional structures to try to eliminate energy uses for bad institutional structures?

Panel Response: That is a difficult question to respond to. Certainly land use control could be one of the alternatives to be looked at. In the planned progress, the agency is planning to look at institutions which can use land use laws, water laws, mining laws, reclamation laws, as they might pertain in terms of either promoting development or preventing development from taking place. As far as this phase of the program is concerned, EPA does have some research going on and is attempting to develop tools for doing the type of mining that was mentioned in association with some of the environmental planning which Congress mandates our agency and on the states.

The technology assessment, focusing on the West, will certainly look at that kind of thing. The project manager for that project is a political scientist. He certainly will focus on land use and institutional problems.

Question: It was noticed that in the current development of the SEAS system, one of the things that is to be obtained from the SEAS system is this optimum ability that would influence acceptability. To that point, are ERDA and EPA talking of developing or using the SEAS system for decision making, or is it envisioned to be used for decision making jointly?

Panel Response: Yes, with regard to the development systems, there is a shared data base between the SEAS system on the one hand and the work at Brookhaven National Laboratory. These projects are being brought closer together. However, these models are only in the development stage, and it's probably some time before they can be used extensively in decision making.